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PART I

Bioventing Pilot Test Work Plan for Building 30, Aboveground Soil Pile, and POL Storage Area Sites Offutt AFB, Nebraska

PART II

Draft Interim Pilot Test Results Report for Building 30 and POL Storage Area Offutt AFB, Nebraska

Prepared For

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Headquarters 55th Air Combat Command (ACC)
Offutt AFB, Nebraska

ES ENGINEERING-SCIENCE

ES
Engineering-Science, Inc.

1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290

July 1993

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PART I

DRAFT

BIOVENTING TEST WORK PLAN FOR BUILDING 30, POL STORAGE AREA, AND ABOVEGROUND SOIL PILE SITES

OFFUTT AFB, NEBRASKA

Prepared for:

Air Force Center for Environmental Excellence

Brooks AFB, Texas

and

Headquarters 55th Air Combat Command (ACC)

Offutt AFB, Nebraska

March 1993

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

BIOVENTING PILOT TEST WORK PLAN FOR BUILDING 30, POL STORAGE AREA, AND ABOVEGROUND SOIL PILE SITES OFFUTT AFB, NEBRASKA

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Headquarters 55th Combat Support Group (SAC)
Offutt AFB, Nebraska

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

March 1993

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FIGURES

DRAFT

BIOVENTING PILOT TEST WORK PLAN FOR BUILDING 30, ABOVEGROUND SOIL PILE, AND POL STORAGE AREA SITES

1.0 INTRODUCTION

This work plan presents the scope of enhanced biological degradation, or "bioventing", pilot tests for treatment of fuel-contaminated soils at three sites located at Offutt Air Force Base, Omaha, Nebraska. At two sites, Building 30, and the petroleum, oils, and lubricants (POL) storage area, *in situ* pilot tests will be performed. At the third site, an aboveground bioventing pilot test will be performed in a test cell constructed using soils previously excavated from the POL area.

The pilot tests have three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil interval, 2) to determine the rates at which indigenous microorganisms will degrade fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination in the soil is remediated to concentrations below regulatory standards.

These pilot tests will be conducted in two phases. The initial phase of the project will consist of construction of vent wells (VWs) and vapor monitoring points (MPs), background MPs, conducting *in situ* respiration tests, and air permeability tests. This initial testing is expected to take approximately 3 weeks. During the second phase, pilot-scale bioventing systems will be installed at each site and monitored over a 1-year period.

If bioventing proves to be an effective means of remediating soils at these sites, pilot test data will be used to design full-scale remediation systems and to estimate the time required for site cleanup. An added benefit of the pilot testing is that a significant amount of the fuel contamination should be biodegraded in the test soils during the 1-year pilot tests.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et al., 1992). This protocol document will also serve as the primary reference for pilot test well designs and the detailed procedures to be used during the test.

2.0 SITE DESCRIPTION

2.1 Building 30

2.1.1 Site Location and History

Building 30 is located just east of SAC Boulevard and northeast of Base Operations. The location of the Building 30 site with respect to the base is shown in Figure 2.1 The locations of Building 30, onsite underground storage tanks (USTs), existing monitoring wells, and previous soil borings are shown on Figure 2.2. The USTs are reported to be 10,000, 1,500, and 560 gallons in size and are located in the grassy area near the northwest corner of the building. The 10,000-gallon tank has been filled with sand; both the 1,500-gallon tank and the 560-gallon tank were active until 1989, and were used to store aviation gasoline for the Offutt Aero Club. Two aviation fuel pumps are located approximately 5 feet from Building 30 (Woodward-Clyde Consultants, 1992). Three pipes believed to be used as remote fill and drain points are located adjacent to the fuel pumps; two have been padlocked, and the third is filled with concrete.

2.1.2 Site Geology

Bioventing technology is applied to the unsaturated soils above the groundwater table. The stratigraphy at this site consists of varying depths of fill with sand, silt and gravel present, underlain by a silty clay loess (Peorian Formation). Figure 2.3 depicts the lithology of the site in cross-section. Groundwater occurs at a depth of approximately 11.5 to 12 feet below ground surface (bgs).

2.1.3 Site Contaminants

The primary soil contaminants at this site are fuel-related petroleum hydrocarbons which have been detected in the soils at depths ranging from 5 to 11 feet bgs. Total recoverable petroleum hydrocarbons (TRPH) were detected at 226 milligrams per kilogram (mg/kg) in soil boring B30-SB1 at a depth of 5.0 to 5.5 feet (Figure 2.2). The volatile organic compounds (VOCs) benzene, toluene, ethylbenzene, and total xylenes (BTEX) were detected in samples collected from the soil borings and borings for monitoring wells at concentrations ranging from undetected to 5.42 mg/kg total BTEX. Groundwater samples had concentrations of TRPH ranging from 2.2 to 126 milligrams per liter (mg/L) and total BTEX concentrations ranging from undetected to 61 mg/L.

2.2 POL Storage Area

2.2.1 Site Location and History

The POL solid waste management unit (SWMU) is located in the south-central part of Offutt AFB and is currently used for the storage of JP-4 jet fuel and diesel fuel. The location of the POL storage area with respect to the base is shown in Figure 2.1. The site proposed for the bioventing pilot study is located near aboveground tank No. 10, in the southwestern part of the POL storage area (Figure 2.4).

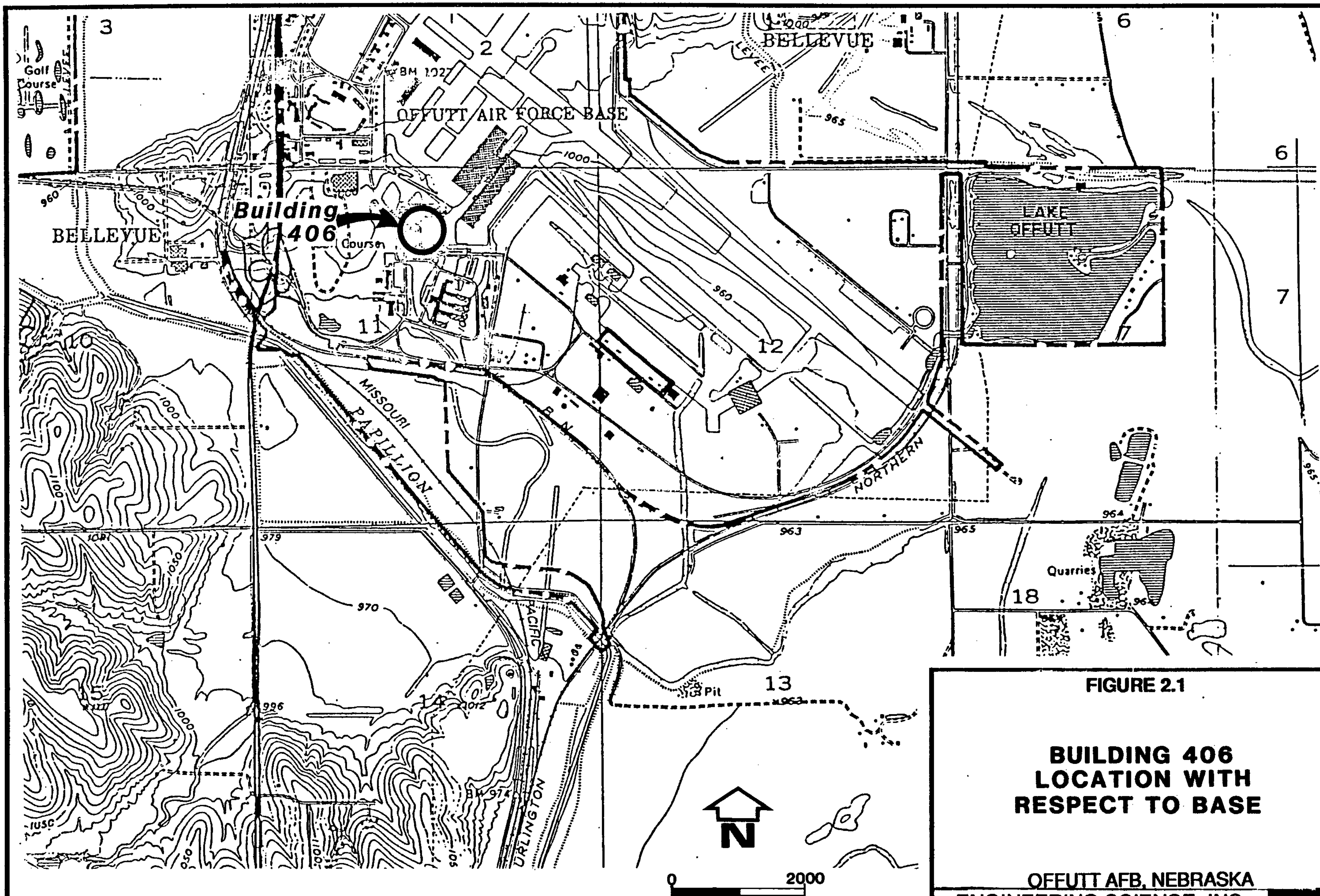

FIGURE 2.1

BUILDING 406 LOCATION WITH RESPECT TO BASE

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Source: Woodward-Clyde Consulants, 1992.

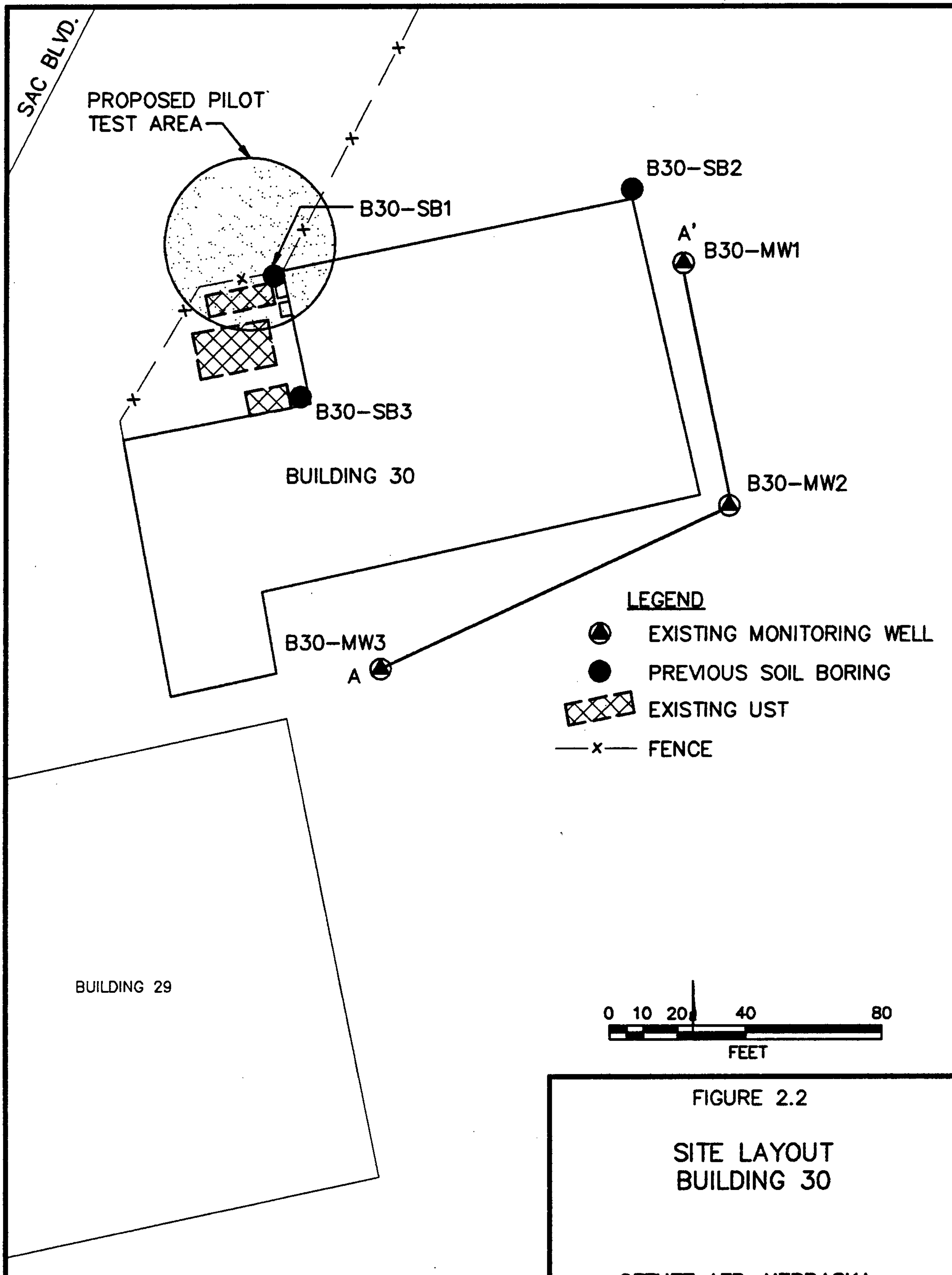

FIGURE 2.2

SITE LAYOUT
BUILDING 30

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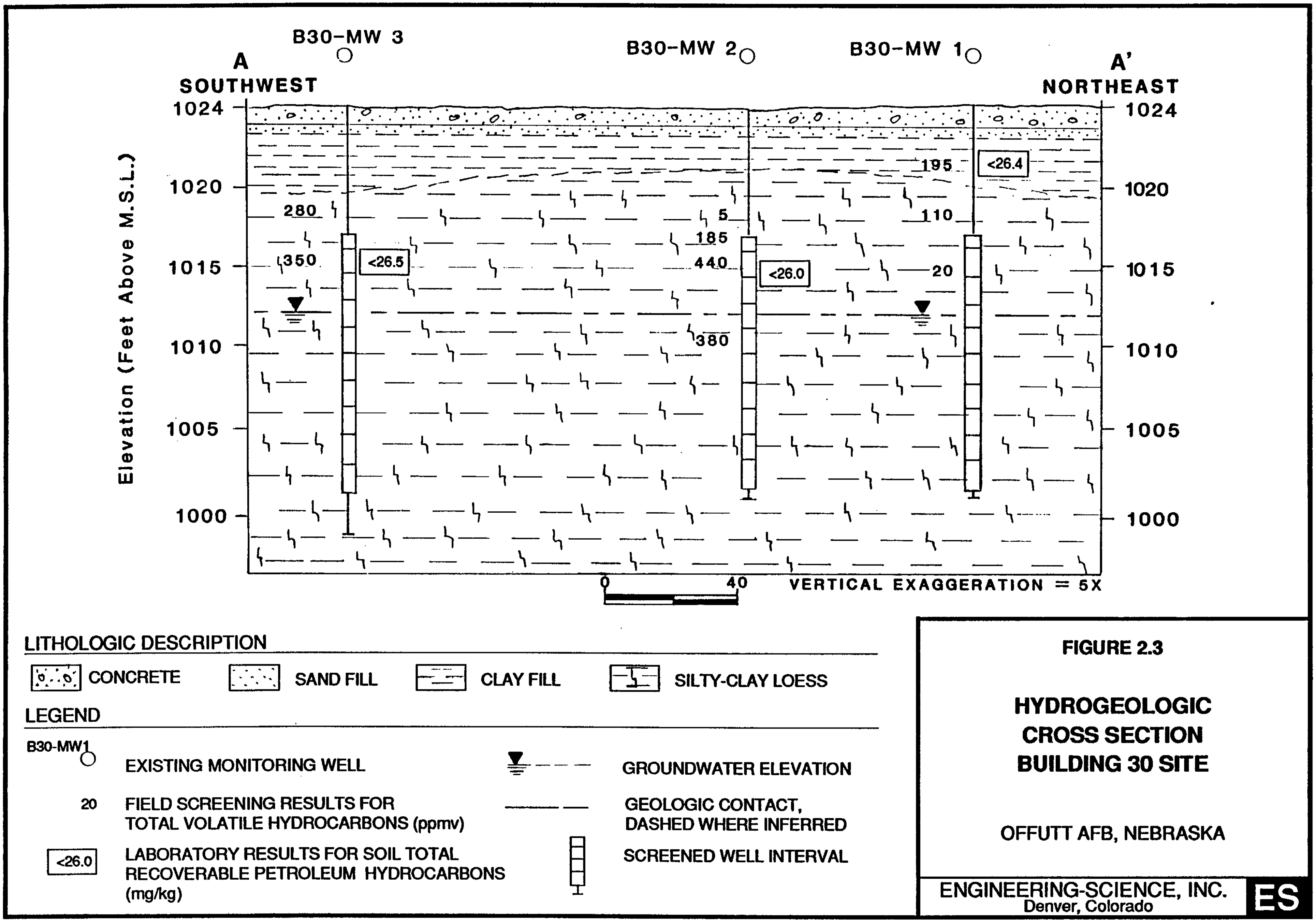

FIGURE 2.3

HYDROGEOLOGIC CROSS SECTION BUILDING 30 SITE

OFFUTT AFB, NEBRASKA

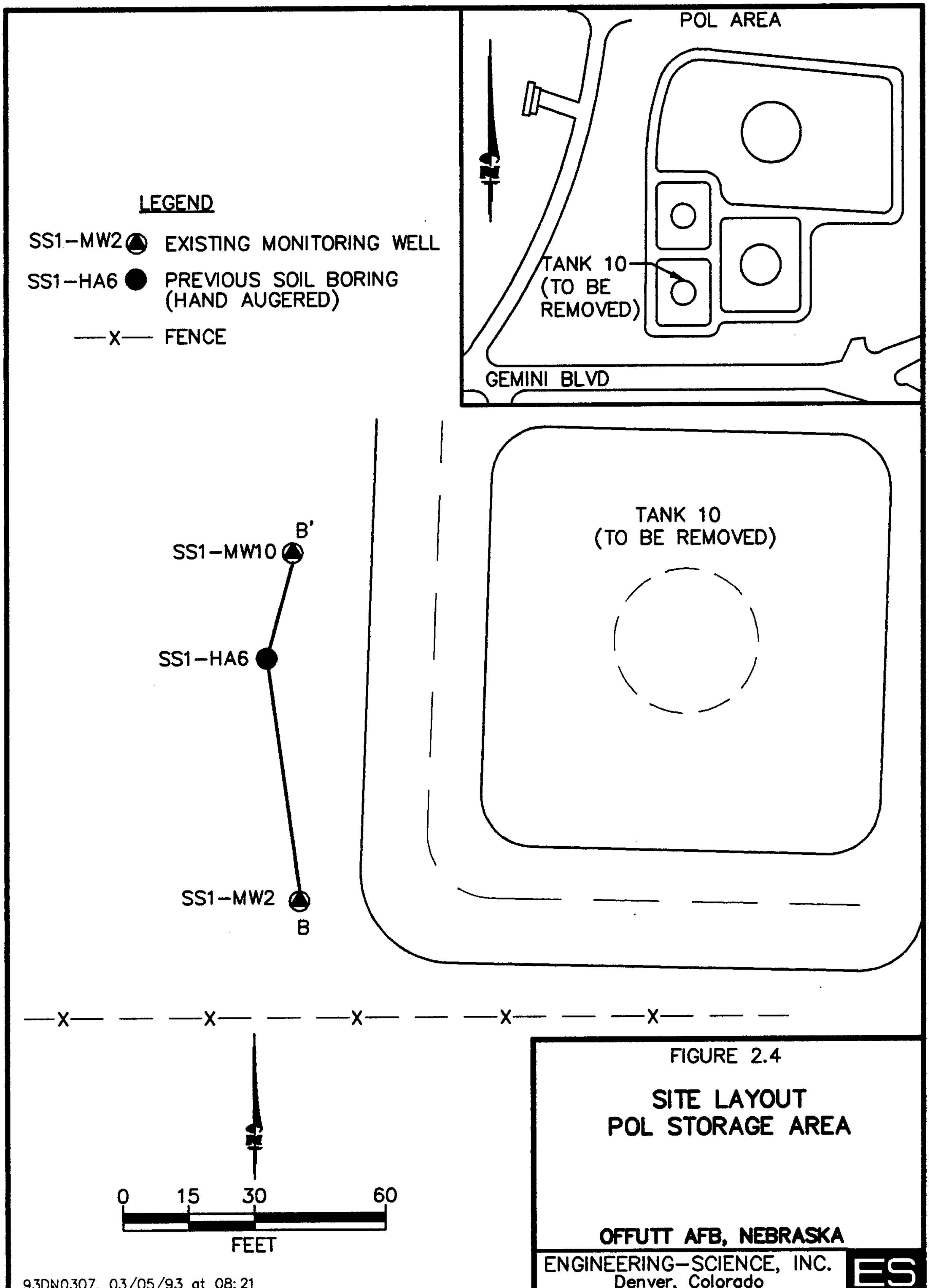

FIGURE 2.4

SITE LAYOUT
POL STORAGE AREA

OFFUTT AFB, NEBRASKA

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Denver, Colorado

2.2.2 Site Geology

The soil profile at this site generally consists of varying depths of sand and silt fill to a depth of 9 to 10 feet, underlain by sandy silt and silty sand alluvium to approximately 25 feet bgs. The lithology of the site is represented on Figure 2.5. Groundwater is typically encountered at depths ranging from 8 to 11 feet bgs; however, groundwater table fluctuations of ±2 feet can occur (Woodward-Clyde Consultants, 1992).

2.2.3 Site Contaminants

The primary soil contaminants at this site are JP-4-derived petroleum hydrocarbons, which have been detected in the soils at depths ranging from 5 to 11 feet bgs. Concentrations of TRPH were detected at 289 mg/kg in the hand-augured borehole SS1-HA6 at a depth of 7.0 feet. BTEX compounds were not detected in this sample; however, polynuclear aromatic hydrocarbons (PAHs) were detected at concentrations of 2,800J micrograms per kilogram (μg/kg). The "J" designation indicates an estimated value. The compounds 2-methylnaphthalene and naphthalene were detected in the soil sample collected from the 7.0-foot interval in borehole SS1-HA6 at concentrations of 1,800J and 1,000J μg/kg, respectively. Higher levels of hydrocarbons are expected closer to Tank 10. Trace levels of trichloroethene (TCE) was also detected in groundwater sampled from monitoring wells installed near the proposed pilot test area, within the POL area. Concentrations ranged from 0.88 micrograms per liter (μg/L) in monitoring well SS1-MW2 to 2.4 μg/L in well SS1-MW10.

2.3 Aboveground Soil Pile

2.3.1 Site Location and History

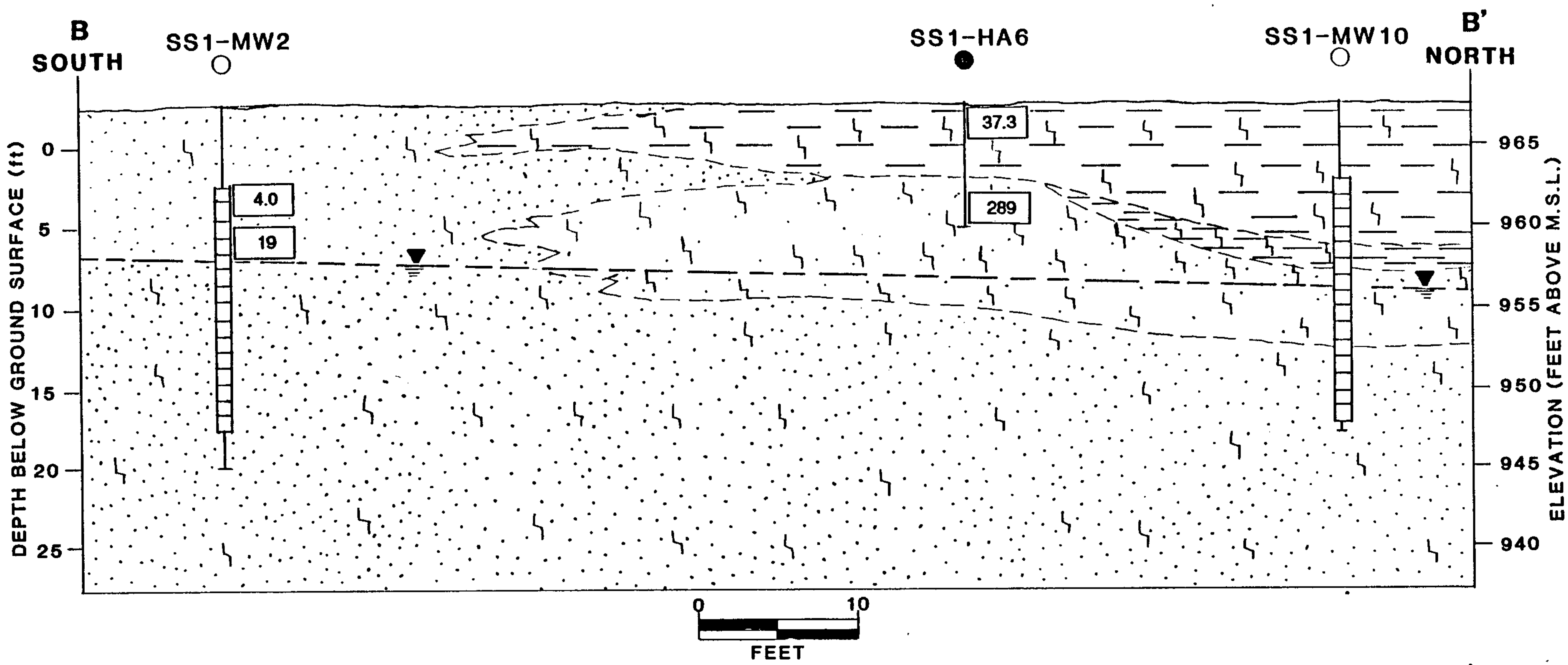
Soil to be treated using an aboveground bioventing system was removed from the POL SWMU, described in Section 2.2, above. The soil was removed from within the POL storage area where construction modifications to a product recovery system have required additional trenching through hydrocarbon-contaminated soil. Hydrocarbon-contaminated soil excavated from a pipe installation trench in this area will be stockpiled on a concrete pad near Building 544 for treatment by an aboveground bioventing installation (Figures 2.1 and 2.6). The site for the construction of the test cell was chosen based on the availability of power, and the existing concrete pad located in a fenced, secured area.

2.3.2 Site Geology

The soils to be treated consist primarily of sand and clay fill as described in Section 2.2.2 and in the boring logs from the site investigation conducted by Woodward-Clyde Consultants (1992).

2.3.3 Site Contaminants

The primary contaminants in the soil excavated from the POL storage area are petroleum hydrocarbons, primarily JP-4 jet fuel and diesel fuel which leaked from the aboveground tanks and underground pipelines at the POL SWMU. The most



LITHOLOGIC DESCRIPTION

SILT WITH CLAY | CLAY WITH SILT | SILT WITH SAND | SAND WITH SILT

LEGEND

SSI-MW1 — EXISTING MONITORING WELL

SSI-HA6 — PREVIOUS SOIL BORING (HAND AUGERED)

37.3 — LABORATORY RESULTS FOR SOIL TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (mg/kg)

GROUNDWATER ELEVATION

GEOLOGIC CONTACT, DASHED WHERE INFERRED

SCREENED WELL INTERVAL

FIGURE 2.5

POL STORAGE AREA HYDROGEOLOGIC CROSS SECTION

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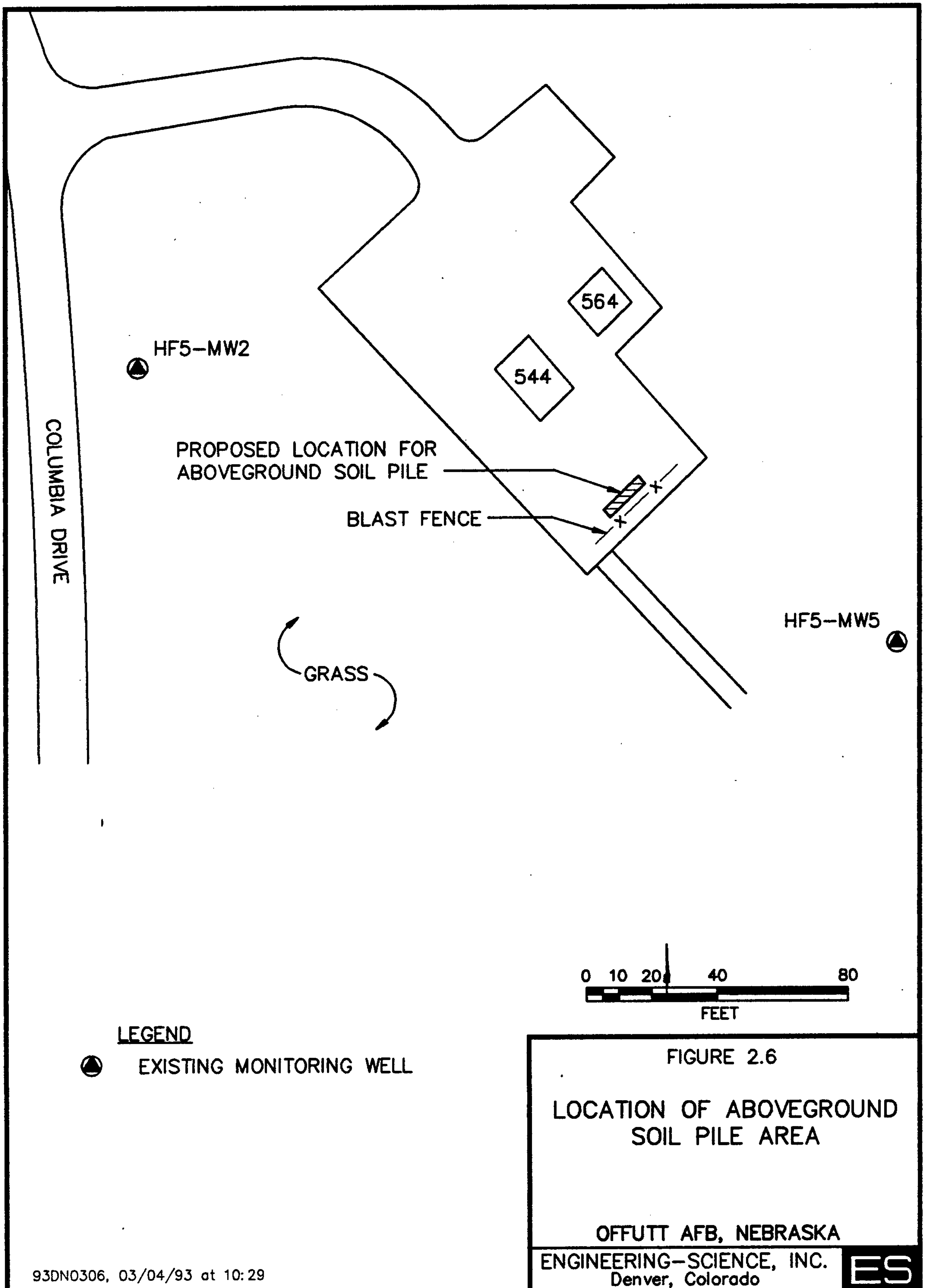

FIGURE 2.6

LOCATION OF ABOVEGROUND SOIL PILE AREA

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Denver, Colorado

ES

recent site investigation of the POL storage area was conducted by Woodward-Clyde Consultants (1992).

Contaminated soil stockpiled from the trenching excavation was segregated from "clean" soil based on field instrument readings. Soil samples from the contaminated soil pile were not collected for laboratory analyses at the time of trenching.

3.0 PILOT TEST ACTIVITIES

The purpose of this section is to describe the work that will be performed by Engineering-Science, Inc. (ES) at the Building 30 site, the aboveground soil pile, and the POL storage area. Activities to be undertaken at the Building 30 and POL storage area sites include siting and construction of a central air injection VW and vapor MPs, performance of an *in situ* respiration test and an air permeability test, and installation of a small bioventing pilot test system for extended testing. Activities at the aboveground soil pile site will include construction of a test cell, performance of a respiration test, an oxygen distribution test, and installation of a small bioventing pilot test system for extended testing. Soil and soil gas sampling procedures and the blower configurations that will be used to inject air (oxygen) into contaminated soils through the VWs and air injection pipes are also discussed in this section. No groundwater treatment or dewatering will take place during the pilot tests. Pilot test activities will be confined to unsaturated soils remediation. Existing monitoring wells will not be used as primary air injection wells. However, monitoring wells which have a portion of their screened interval above the water table may be used as vapor MPs or to measure the composition of background soil gas.

3.1 Layout of Pilot Test Components

3.1.1 Building 30

A general description of criteria for siting a VW and MPs is included in the protocol document (Hinchee et al., 1992). Figure 3.1 indicates the proposed locations of the VW and MPs at Building 30 site. The final locations of these wells may vary slightly from the proposed locations if significant fuel contamination is not observed in the boring for the VW. Based on previous site investigation data, the VW should be located approximately 10 feet northwest of Building 30, as indicated on Figure 3.1. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the generally fine-grained composition of the soils at this site and the experience that ES has had with similar soil types, the potential radius of venting influence around the central VW is expected to be approximately 25 to 30 feet. Three vapor MPs (MPA, MPB, and MPC) will be located within a 25-foot radius of the VW (Figure 3.1).

3.1.2 POL Storage Area

Figure 3.2 indicates the proposed locations of the VW and MPs at the proposed pilot test location. The final locations of the wells may vary from the proposed

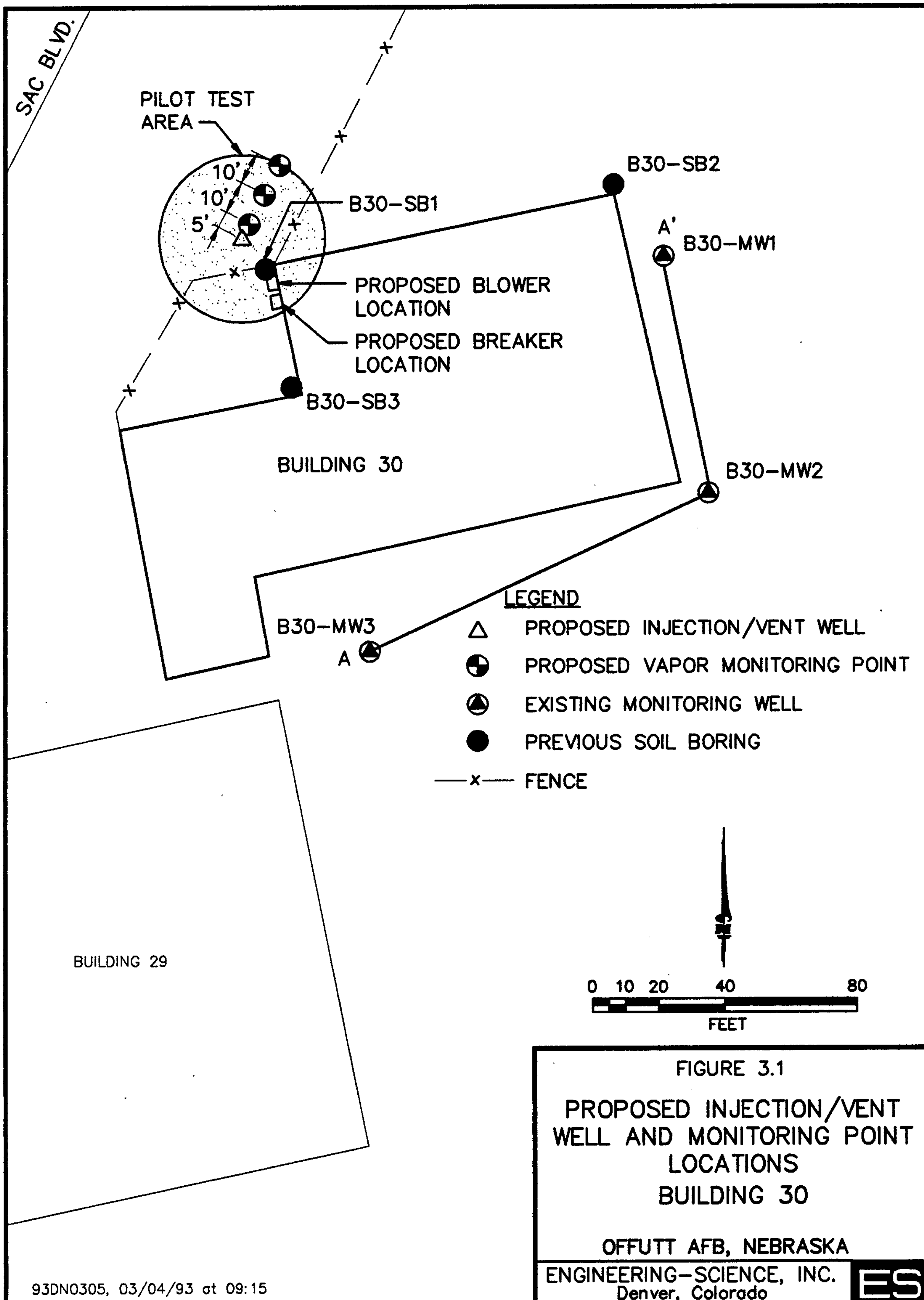

FIGURE 3.1

PROPOSED INJECTION/VENT WELL AND MONITORING POINT LOCATIONS BUILDING 30

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Denver, Colorado

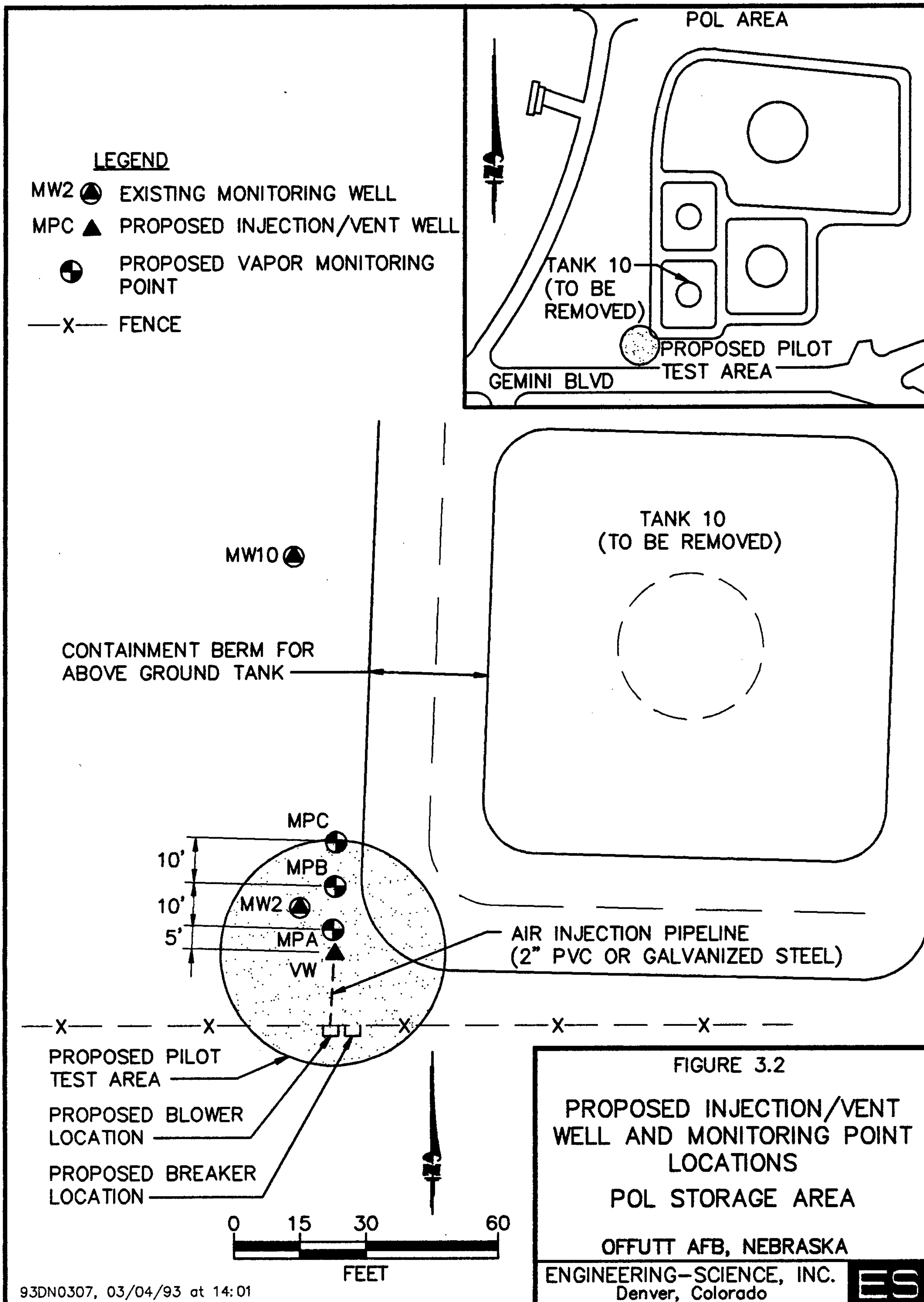

FIGURE 3.2

PROPOSED INJECTION/VENT WELL AND MONITORING POINT LOCATIONS

POL STORAGE AREA

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

locations due to utility interference or lack of sufficient contamination at this site. A preliminary soil gas survey is planned to determine the suitable placement of the VW and MPs. Based on the previous site investigation data, the VW should be placed approximately 15 feet north of the POL area fence and 12 feet southeast of monitoring well SS1-MW2. Soils in this area are expected to be oxygen depleted (<2%) due to high hydrocarbon levels, and increased biological activity should be stimulated by oxygen-rich soil gas ventilation during pilot test operations.

Due to the generally fine-grained composition of the soils, the shallow contamination at this site, and the experience that ES has had with similar soil types at Building 548, the approximate radius of venting influence around the central VW is expected to be approximately 25 feet. Three vapor MPs (MPA, MPB, MPC) will be located within a 25-foot radius of the VW (Figure 3.2).

3.1.3 Aboveground Soil Pile

An aboveground soil pile test cell will be constructed at this site for the pilot test. Figure 3.3 shows the proposed soil pile configuration and locations of air injection pipes, the air outlet pipe, MPs, and other components. This configuration is based on the currently estimated volume of soil to be treated. If additional hydrocarbon-contaminated soil is available to add to the initial soil pile, the physical design parameters of this system (e.g., overall size, air injection pipe screen length, MP depth) will be modified as needed. The soil excavated from the POL storage area will be placed on a section of 10 mil polyethylene sheeting overlying a concrete pad. The test cell will have a rectangular form approximately 20 feet by 12 feet, and 4 feet high (Figure 2.3). This aboveground soil pile will be covered by another sheet of 10 mil polyethylene and sealed around the edges with sand bags or cinder blocks. Two air injection pipes and one vent pipe will be placed in a horizontal configuration. The screen for the two vapor monitoring points will be placed approximately 0.5 feet above the base of the test cell.

3.2 Venting Wells

3.2.1 Building 30

The VW at the Building 30 site will be constructed of 4-inch inside-diameter (ID) Schedule 40 polyvinyl chloride (PVC) casing, with a 5-foot interval of 0.04-inch slotted screen set at 8 to 13 feet bgs. Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6-9 grain size, and will be placed in the annular space of the screened interval. A 4.5-foot layer of bentonite will be placed directly over the filter pack. The bentonite, consisting of granular bentonite or bentonite pellets, will be hydrated in place with potable water. The remaining annular space will then be filled with bentonite/cement grout to the ground surface. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.4 illustrates the proposed VW construction for this site.

3.2.2 POL Storage Area

The VW at the Building 30 site will be constructed of 4-inch ID Schedule 40 PVC casing, with a 5-foot interval of 0.04-inch slotted screen set at 5 to 10 feet bgs.

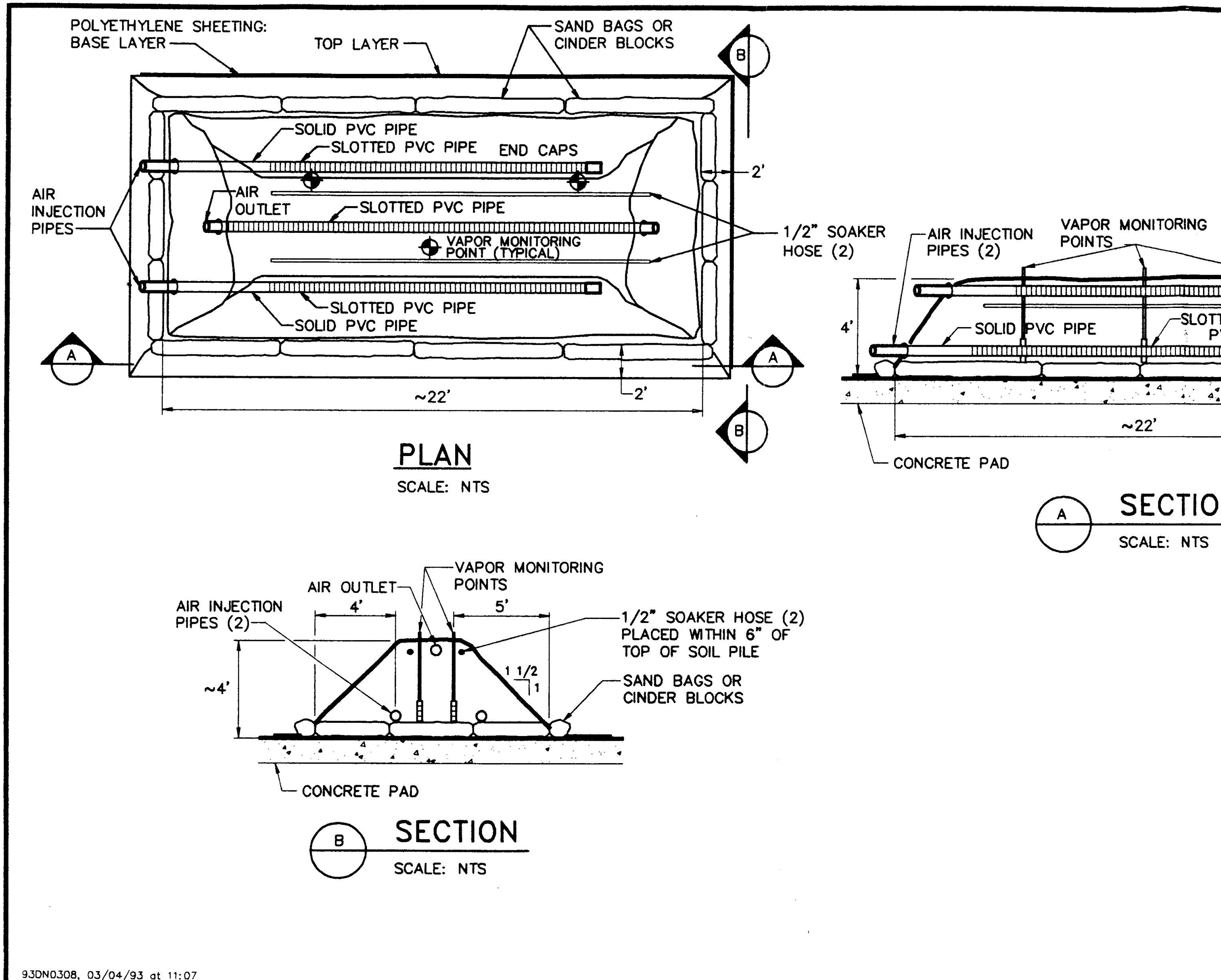

FIGURE 3.3

PROPOSED CONFIGURATION OF ABOVEGROUND SOIL PILE BIOVENTING SYSTEM

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

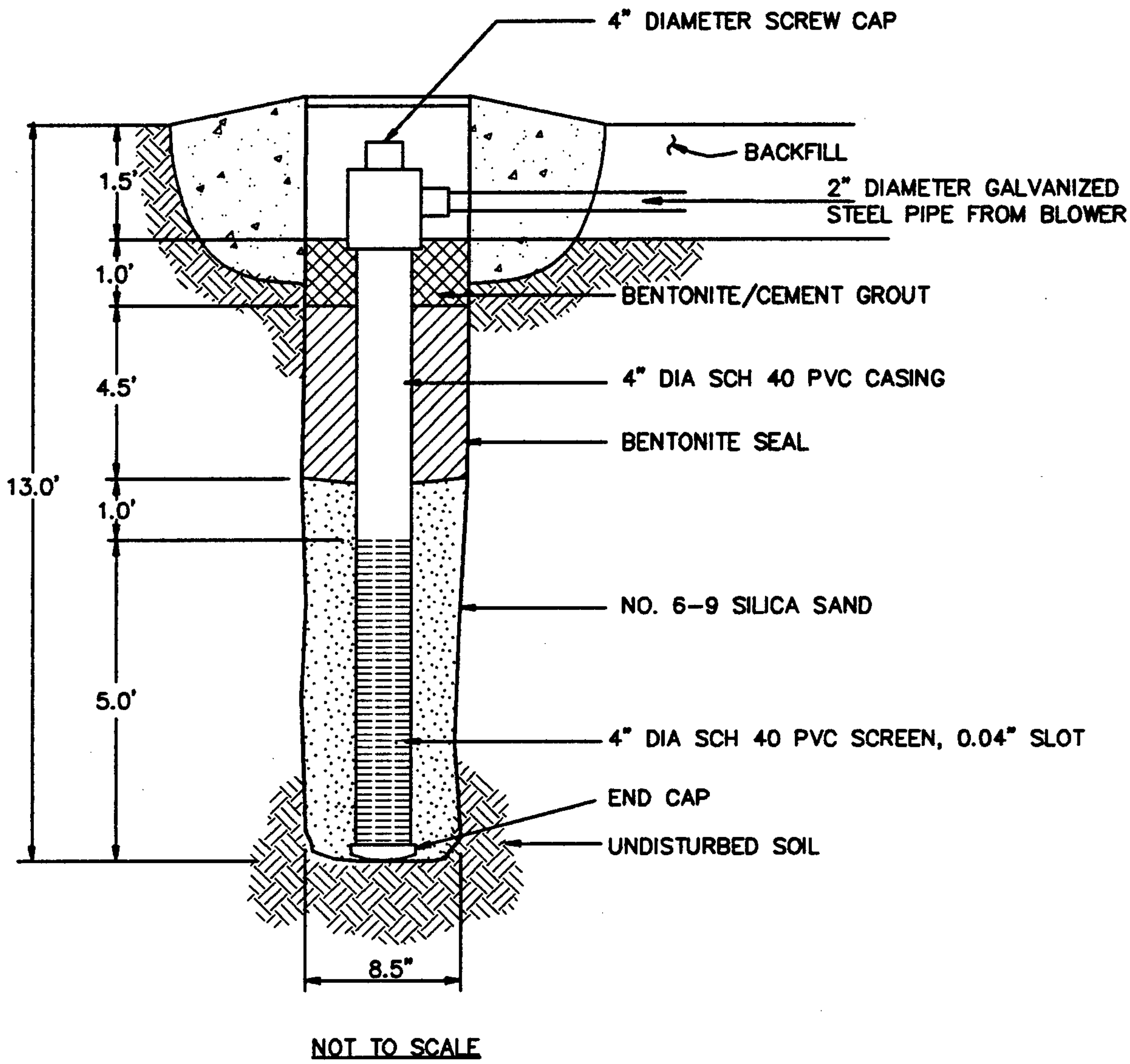

FIGURE 3.4

PROPOSED INJECTION/
VENT WELL
CONSTRUCTION DETAIL
BUILDING 30

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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Flush-threaded PVC casing and screen with no organic solvents or glues will be used. The filter pack will be clean, well-rounded silica sand with a 6-9 grain size, and will be placed in the annular space of the screened interval. A 2-foot layer of bentonite will be placed directly over the filter pack. The bentonite, consisting of granular bentonite or bentonite pellets, will be hydrated in place with potable water. The remaining annular space will then be filled with bentonite/cement grout to the ground surface. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. Figure 3.5 illustrates the proposed VW construction for this site.

3.2.3 Aboveground Soil Pile

The two air injection pipes and a single air outlet pipe at the aboveground soil pile site will be constructed of 2-inch ID Schedule 40 PVC casing, with a 14-foot interval of 0.10-inch slotted screen set horizontally at approximately 0.5 feet aboveground surface (ags). Flush-threaded PVC casing and screen with no organic solvents or glues will be used. A filter pack will not be used for the air injection pipes; instead the PVC will inject air directly into the adjacent soil. Figure 3.3 illustrates the proposed VW construction for this site.

3.3 Vapor Monitoring Points

3.3.1 Building 30

A typical multidepth vapor MP installation for the Building 30 site is shown in Figure 3.6. Soil gas oxygen and carbon dioxide concentrations will be monitored with vapor probes installed at depth intervals of 5 feet, and 10.5 feet bgs at each MP location. Soil temperature will be monitored using thermocouples installed at depths of 5 feet and 10.5 feet bgs at MPA only. Vapor probes are constructed of 6-inch-long sections of 1-inch-diameter PVC well screen with 0.25-inch-diameter Schedule 80 PVC riser pipe (Figure 3.6). Each vapor probe will be placed within a 1- to 1.5-foot layer of 6-9 silica sand. Multidepth monitoring will confirm that the entire contaminated soil profile is receiving oxygen, and will allow measurement of fuel biodegradation rates at the two depths. The annular space between these two intervals will be sealed with bentonite to isolate the intervals. The bentonite seals will consist of bentonite pellets or granular bentonite hydrated in place. The bentonite within 2 feet above and below the sand packs will be placed in approximately 6-inch-thick layers to assure complete saturation and hydration of the bentonite before placement of subsequent layers. Additional details on VW and MP construction are presented in Section 4 of the protocol document.

3.3.2 POL Area

A typical multidepth vapor MP installation for the POL Area site is shown in Figure 3.7. Soil gas oxygen and carbon dioxide concentrations will be monitored with vapor probes installed at depth intervals of 4.5 feet and 7.5 feet bgs at each MP location. Soil temperature will be monitored using thermocouples installed at depths of 4.5 feet and 7.5 feet bgs at MPA only. Vapor probes are constructed of 6-inch-long sections of 1-inch-diameter PVC well screen with 0.25-inch-diameter Schedule 80 PVC riser pipe. Each vapor probe will be placed within a 1- 1.5-foot

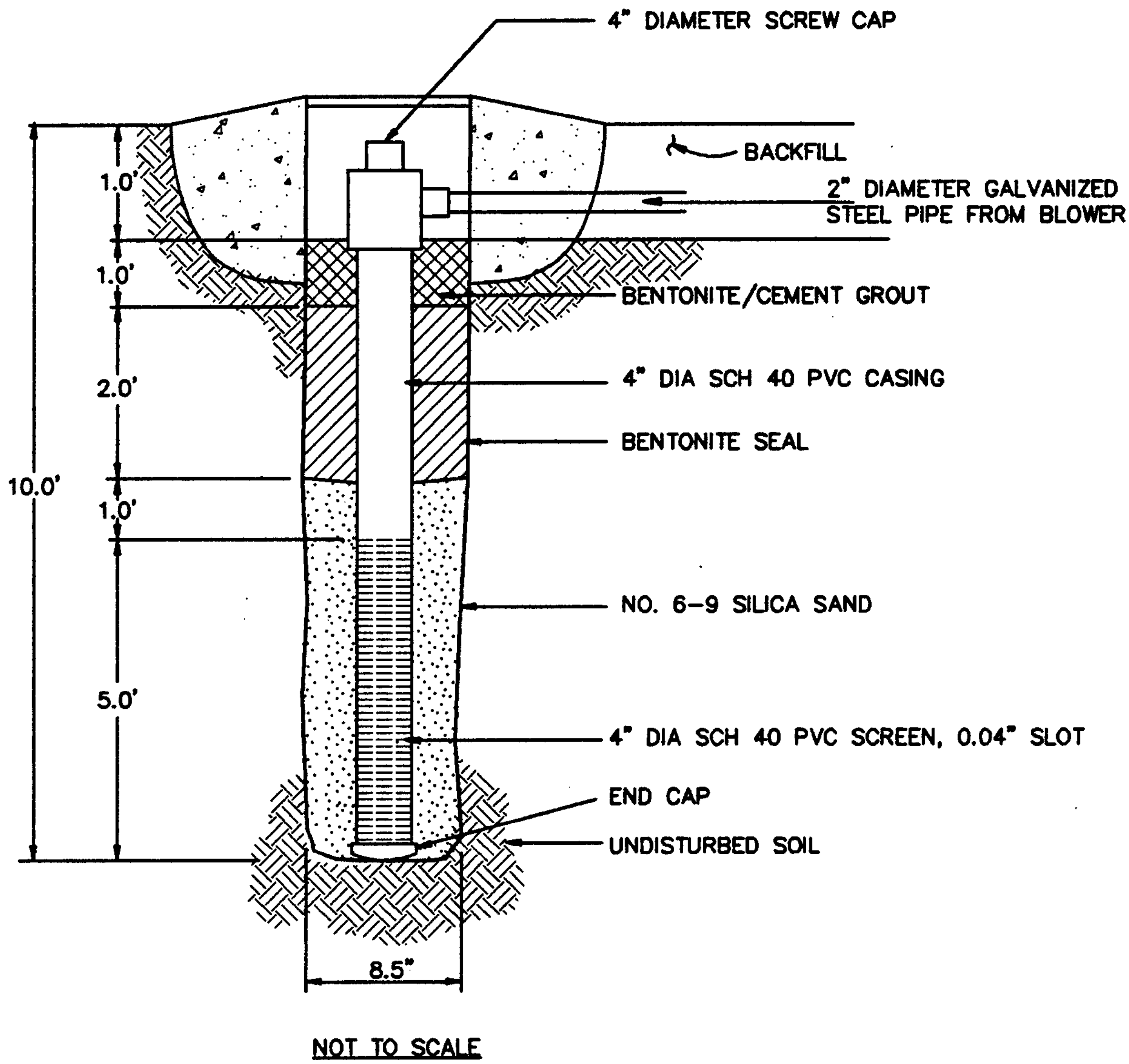

FIGURE 3.5

PROPOSED INJECTION/
VENT WELL
CONSTRUCTION DETAIL
POL STORAGE AREA

OFFUTT AFB, NEBRASKA

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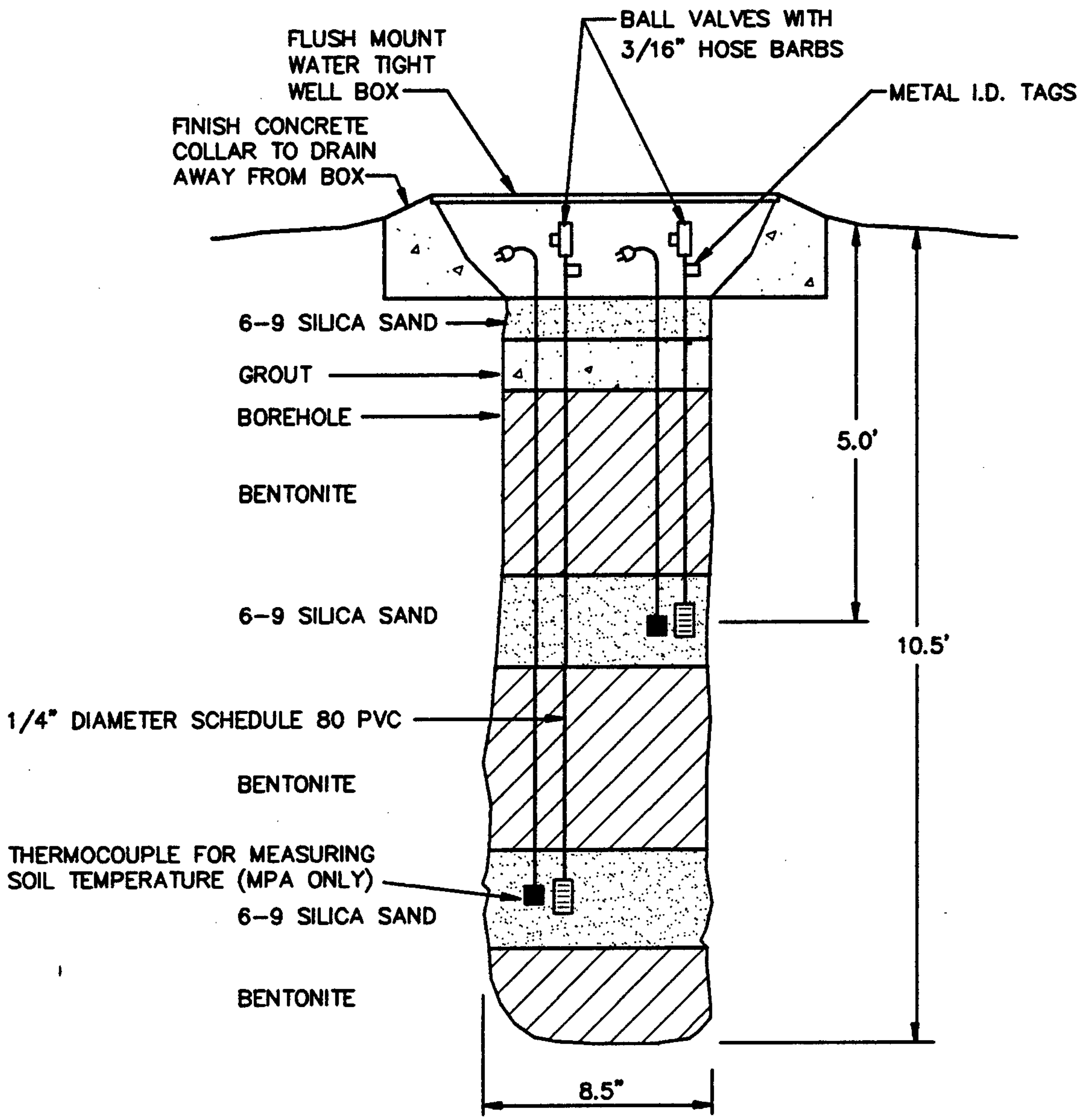

FIGURE 3.6

PROPOSED
MONITORING POINT
CONSTRUCTION DETAIL
BUILDING 30

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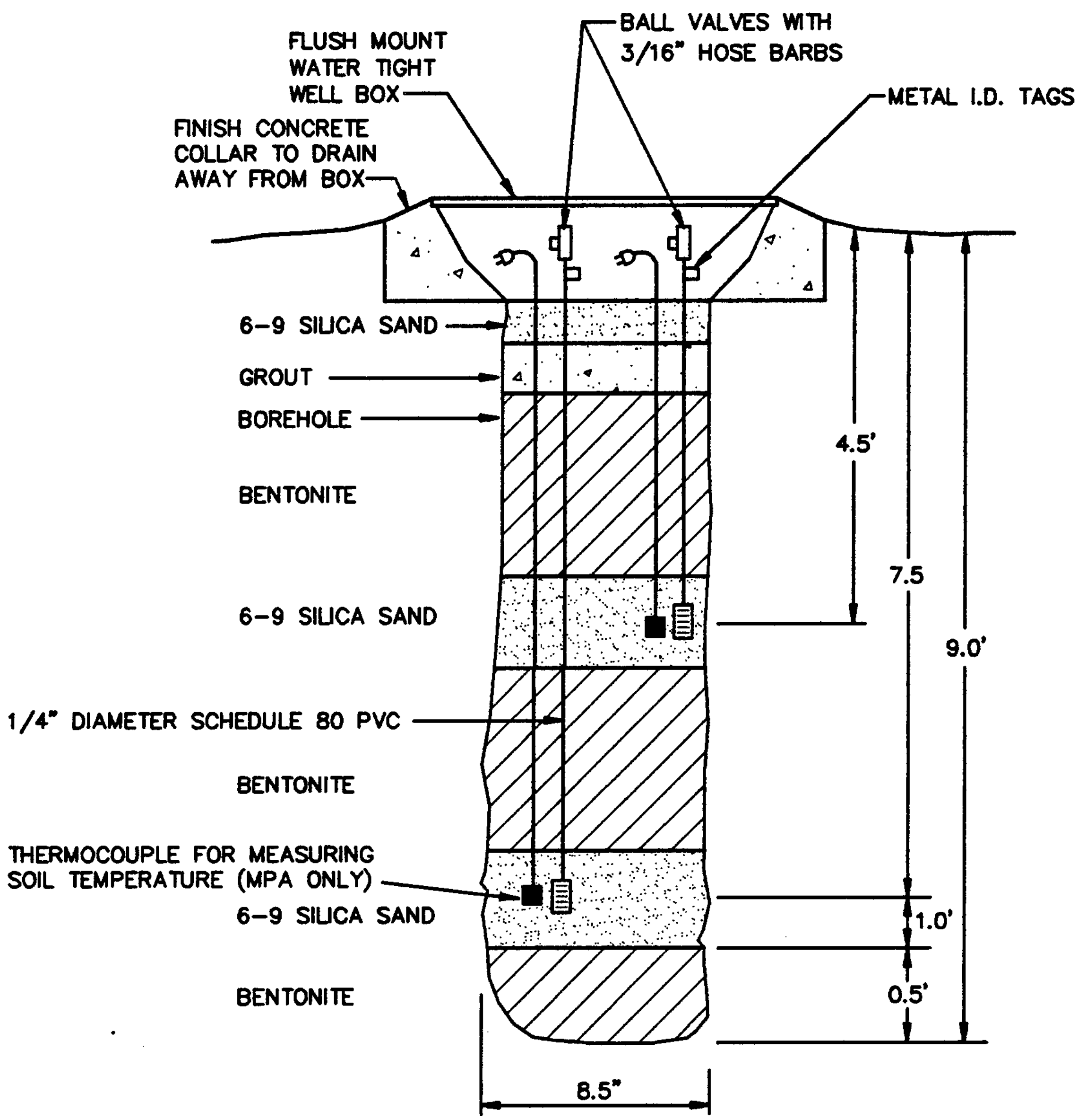

FIGURE 3.7

PROPOSED MONITORING POINT CONSTRUCTION DETAIL POL STORAGE AREA

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layer of 6-9 silica sand. Multidepth monitoring will confirm that the entire contaminated soil profile is receiving oxygen, and will allow measurement of fuel biodegradation rates at the three depths. The annular space between these two intervals will be sealed with bentonite to isolate the intervals. The bentonite seals will consist of bentonite pellets or granular bentonite hydrated inplace. The bentonite within 2 feet above and below the sand packs will be placed in approximately 6-inch thick layers to assure complete saturation and hydration of the bentonite before placement of subsequent layers. Additional details on VW and MP construction are presented in Section 4 of the protocol document.

3.3.3 Aboveground Soil Pile

Three vapor MPs will be constructed for the aboveground soil pile. Each MP will consist of a 6-inch-long section of 1-inch-diameter PVC well screen with 0.25-inch-diameter Schedule 80 PVC riser pipe. A hand auger will be used to bore into the soil pile if the soil is consolidated enough, and the MP will be constructed as described for the belowground MPs. The vapor probe will be placed within a 1-foot layer of 6-9 silica sand. A 1-foot bentonite seal will be placed on top of the sand layer. The bentonite seal will consist of bentonite pellets or granular bentonite hydrated in place.

3.4 Background Monitoring Point

The construction of an additional vapor MP will be required to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in situ* respiration test described in Section 3.8. This background well would be installed in an area of uncontaminated soil and in the same stratigraphic formation as the MPs to be installed at Building 30 site and the POL storage area. The background well would be similar in construction to the MPs (Figures 3.5 and 3.7), and would be screened at two depths. The background well should also be located within 200 feet of a 100 volt power receptacle. ES will require some assistance from Offutt AFB in selecting an appropriate location for the proposed background well.

3.5 Handling of Drill Cuttings

Cuttings will be collected in U.S. Department of Transportation (DOT) approved containers. The containers will be labeled and staged on pallets at the site. Drill cuttings will become the responsibility of Offutt AFB, and will be analyzed, handled, and disposed of in accordance with the current procedures for ongoing remedial investigations. This bioventing pilot test project is expected to generate approximately eight 55-gallon drums of drill cuttings.

3.6 Handling of Drilling Decontamination Water

Drilling equipment will be cleaned at the decontamination pad located to the west of Building D. Waste water generated during the decontamination of drilling equipment must be analyzed for water quality in order to discharge to the sanitary sewer. The water will only be discharged to the sanitary sewer if the following conditions are met:

- pH must be between 6.5 and 9.7;
- no inorganics detected;
- must not register significantly above background levels for VOCs; and
- must not have visual or olfactory signs of contamination.

Decontamination water not meeting the above conditions will be drummed and labeled according to Base requirements. Drums will be stored in the holding area adjacent to the decontamination pad.

3.7 Soil and Soil Gas Sampling

3.7.1 Soil Samples

Three soil samples will be collected from each pilot test area during the installation of the VWs and MPs and during construction of the soil pile. Sampling procedures will follow those outlined in the protocol document. At the Building 30 and POL storage area sites, one sample will be collected from the most contaminated interval of the VW boring, and one sample will be collected from the interval of highest apparent contamination in each of borings for the two MPs closest to the VW (MPA and MPB). Three composite soil samples will be collected from the soil pile test cell at the initiation of the test. Each sample will be composited from soil collected with a hand auger at three depths within the boring used for VMP construction. Soil samples will be analyzed for TRPH, BTEX, soil moisture, pH, particle sizing, alkalinity, total iron, and nutrients.

Samples for TRPH and BTEX analyses obtained from the Building 30 and POL storage area sites will be collected using a split-spoon sampler containing brass tube liners. Soil samples collected in the brass tubes will be immediately trimmed, and the ends of the tubes will be sealed with aluminum foil or Teflon® fabric held in place by plastic caps. Respiration tests will be performed at the two MP locations within the center of the bioventing pile. At the end of the oxygen distribution test described in Section 3.11 for the aboveground soil pile, the air injection blower will be shut off. Oxygen and carbon dioxide levels from the three soil gas monitoring points will be measured for 48 to 72 hours. Soil samples collected for physical parameter analyses will either be collected and handled in the same manner as TRPH and BTEX samples, or placed into glass sample jars. Soil samples will be labelled following the nomenclature specified in the protocol document (Section 5), wrapped in plastic, and placed in a cooler for shipment. A chain-of-custody form will be filled out, and the cooler will be shipped to the ES laboratory in Berkeley, California, for analysis. This laboratory has been audited by the Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.7.2 Soil Gas Samples

A total hydrocarbon vapor analyzer will be used during drilling to screen split-spoon samples for intervals of high fuel contamination. At the Building 30 and POL storage area sites, initial and final pilot test soil gas samples will be collected in SUMMA® canisters in accordance with the *Field Sampling Plan* (Engineering-

Science, Inc., 1992) from the VW and from the MPs closest to and furthest from the VWs (MPA and MPC). Additionally, initial and final soil gas samples will be collected in SUMMA® canisters from the exhaust manifold and from the two soil pile MPs. These soil gas samples will be used determine the reduction in BTEX and total volatile hydrocarbons (TVH) during the 1-year test, and to detect migration of these vapors from the source areas.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the Air Toxics, Inc. laboratory in Rancho Cordova, California for analysis.

3.8 Blower Systems

A 1-horsepower regenerative blower capable of injecting 30 standard cubic feet per minute (scfm) at 1 pounds per square inch will be used to conduct the initial air permeability tests at Building 30 and the POL storage area. Air injection rates of 10 to 30 scfm are anticipated for initial testing. A smaller ½-horsepower blower may be used at the aboveground bioventing site. Figure 3.8 is a schematic of a typical air injection system used for pilot testing. The maximum power requirement anticipated for these pilot tests is 230-volt, single-phase, 30-amp service at each site.

At each site, the base is requested to provide a breaker box with 230-volt/single-phase/30-amp power, one 230-volt receptacle, and two 115-volt receptacles. For the Building 30 site and the aboveground soil pile, the new breaker box should be located as near as possible to the proposed VW location. The new breaker box for the POL storage area should be located outside of any explosion proof areas if possible (Figure 3.2). Depending on the availability of a plant electrician, a base electrician or a licensed electrician subcontracted to ES will perform the connections to existing power sources and assist in wiring the blowers to line power. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

3.9 In Situ Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Section 5.7 of the protocol document describes the procedures to be used for the *in situ* tests (Hinchee et al., 1992). At the Building 30 and POL storage area sites, respiration tests will be performed at the VW and every vapor MP where bacterial degradation of hydrocarbons is indicated by low oxygen levels (<2%) and elevated carbon dioxide concentrations in the soil gas. Air will be injected into MPs at the screened intervals containing low levels of oxygen. A 20-hour period of air injection using a 1 cubic-foot-per-minute (cfm) air pump will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be cut off, and oxygen and carbon dioxide levels will be monitored for the following 48 to 76 hours.

Respiration tests will be performed at the three MP locations within the center of the bioventing pile. At the end of the oxygen distribution test described in Section

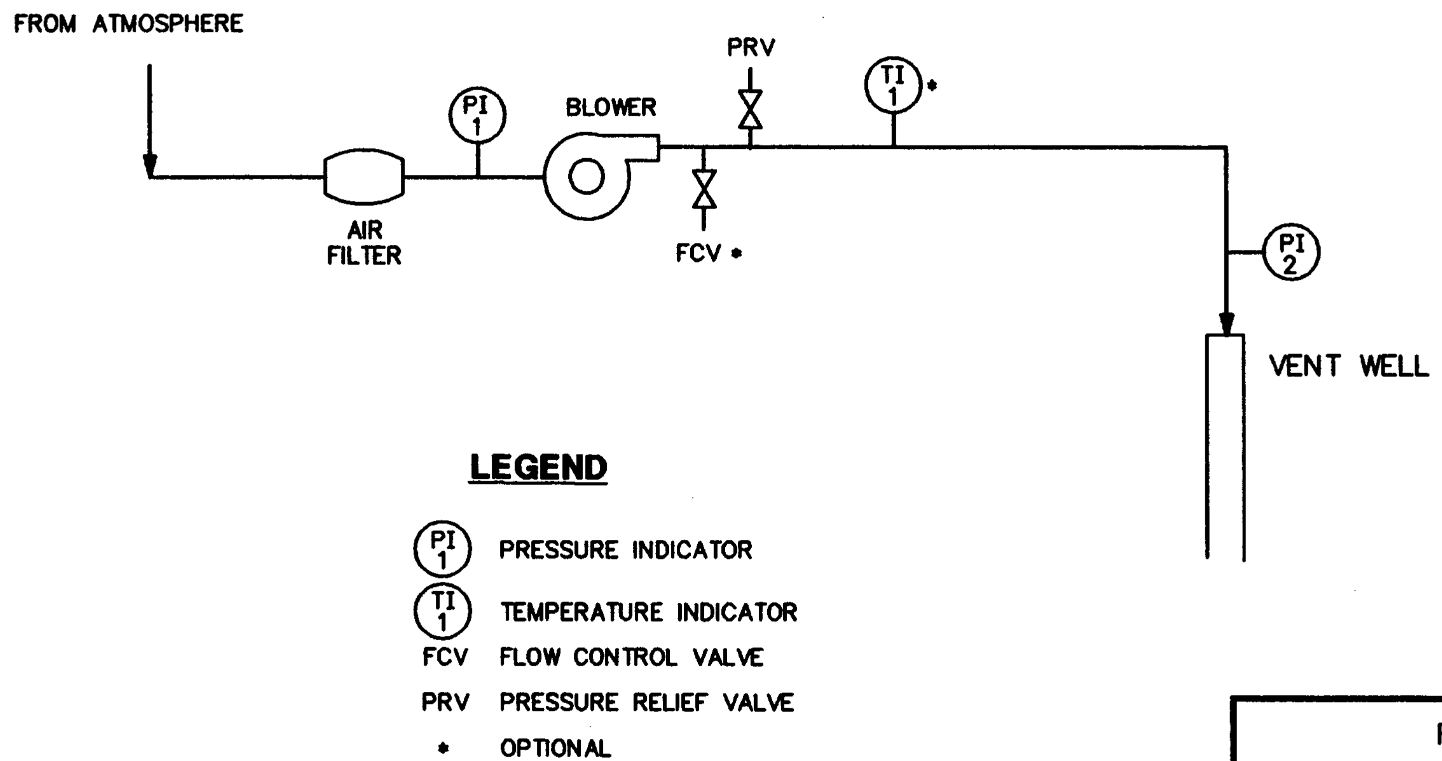

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FIGURE 3.8

BLOWER SYSTEM
INSTRUMENTATION DIAGRAM
FOR AIR INJECTION

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

3.11 for the aboveground soil pile, the air injection blower will be shut off. Oxygen and carbon dioxide levels from the two soil gas MPs will be measured for 48 to 72 hours. The decline in oxygen and increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. At the Building 30 and POL storage area sites, a helium tracer will also be injected into four MPs with low initial oxygen levels and monitored for the duration of the respiration test to determine the effectiveness of the bentonite seals between screened intervals. Helium will not be used in the bioventing soil pile. The presence of atmospheric oxygen in the space surrounding the bioventing pile negates the purpose of this test. The only potential for oxygen leakage is from the atmosphere into the pile, and not vice-versa.

3.10 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection VW. At each site, air will be injected into the VW using the 10 to 30-scfm test blower unit, and pressure response will be measured at each MP with differential pressure gages to determine the region influenced by the unit. Oxygen will also be monitored in the MPs to ascertain whether oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 4 to 8 hours will be performed at the Building 30 and POL storage area sites.

3.11 Oxygen Distribution Test for Aboveground Soil

The objective of the oxygen distribution test is to determine the extent of the bioventing pile that is effectively aerated with the blower system. Following construction and covering of the bioventing pile, the distribution of oxygen will be measured in the pile with soil gas probes. The blower will remain off for initial measurements to verify that active air injection will be required to enhance biodegradation in the soil pile. A period of 1 to 3 days after covering the pile may be necessary for soil air to reach a concentration approaching 0% oxygen in the middle of the pile due to microbial uptake of oxygen related to petroleum biodegradation. Oxygen, carbon dioxide and volatile hydrocarbons will be measured at the three MP locations along the centerline of the soil pile. A sample of the soil gas will be collected with a Summa® canister from two MPs immediately following verification of oxygen-depleted air in the middle of the pile. In addition to soil gas measurements, the exhaust air from the pile will be sampled and analyzed for oxygen, carbon dioxide, and volatile hydrocarbons 24 hours after initial start-up of the blower system. At the same time, an exhaust gas sample will be collected in a Summa® canister for laboratory analysis.

3.12 Extended Pilot Test Bioventing Systems

Long-term bioventing pilot systems will also be installed at all three sites. The blower systems will be chosen based upon the results of the initial respiration and air permeability tests. However, it is anticipated that the extended test blowers will have flow rates in the range of 5 to 15 cfm and will not exceed 1 horsepower. The blowers will be housed in small, prefabricated sheds to provide protection from the weather. Depending on the availability of a base electrician, a base electrician or a

licensed electrician subcontracted to ES will perform the connections between existing breaker boxes and the blowers and starters. The power sources will be the same as those used for the initial pilot tests.

The systems will be in operation for 1 year, and every 6 months ES personnel will conduct *in situ* respiration tests to monitor the long-term performance of these bioventing systems. Approximately 200 gallons of water will be slowly added to the soil pile each month during June-September. Soaker hoses placed near the top of the pile will be used to introduce water to the pile. ES personnel will instruct Offutt AFB personnel on how to perform the water addition. Weekly system checks will be performed by Offutt AFB personnel. If required, major maintenance of the blower units will be performed by ES personnel. Detailed blower system information and maintenance schedules will be included in the operation and maintenance (O&M) manuals provided to the plant. More detailed information regarding the test procedures can be found in the protocol document.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The procedures that will be used at the Building 30 and POL storage area sites to measure the air permeability of the soil and *in situ* respiration rates are described in Sections 4 and 5 of the protocol document. No exceptions to the protocol procedures are anticipated for these sites. The procedures for the performance of the aboveground soil pile bioventing pilot test are modifications of the procedures described in the protocol document.

5.0 BASE SUPPORT REQUIREMENTS

The following Offutt AFB support is needed prior to the arrival of the drilling subcontractor and the ES test team:

- Assistance in obtaining drilling and digging permits from Offutt AFB.
- Installation of a new breaker box at Building 30, mounted on the building wall as close as practical to the proposed blower location (Figure 3.1). The breaker box should include 230-volt, 30-amp, single-phase service with one 230-volt receptacle and two 115-volt, 30-amp receptacles.
- Installation of the new breaker boxes at the sites, for the aboveground soil pile and the POL area. It is preferred to have a non-explosion proof configuration by mounting the POL area breaker box outside of the south fence. The breaker boxes for each area should include 230-volt, 30-amp, single-phase service with one 230-volt receptacle and two 115-volt, 30-amp receptacles.
- Provision of any paperwork required to obtain gate passes and security badges for approximately three ES employees, two drillers, and an electrician (if a base electrician is not available). Vehicle passes will be needed for one truck and a drill rig.

During the initial testing, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as close to the sites as practical. No utilities are required for this trailer.
- Parking space for one 8x20-foot field trailer located as close to the pilot test areas as practical. No utilities are required for this trailer.
- The use of a facsimile machine for transmitting 15 to 20 pages of test results.
- A decontamination pad where the driller can clean augers between borings.
- Acceptance of responsibility by the base for drill cuttings from VW and MP borings, including any drum sampling to determine hazardous waste status.

During the 1-year extended pilot tests, base personnel will be required to perform the following activities:

- Check the blower systems once per week to ensure that they are operating and to record the air-injection pressures. ES will provide a brief training session on this procedure.
- If a blower stops working, notify Mr. Jim Walters, Mr. Doug Downey, ES-Denver (303) 831-8100, or Captain Chung Yen, Air Force Center for Environmental Excellence (AFCEE) (210) 536-5241.
- Arrange site access for an ES technician to conduct *in situ* respiration tests approximately 6 months and 1 year after the initial pilot test.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan.

Event	**Date**
Draft Test Work Plan to AFCEE/Offutt AFB	March 5, 1993
Begin Pilot Tests	April 21, 1993
Complete Initial Pilot Tests	May 13, 1993
Interim Results Report	June 25, 1993
Respiration Tests	November 1993
Final Respiration Tests	May 1994

7.0 POINTS OF CONTACT

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SS SG/DEVI Bldg A
Offutt AFB, NE 68113-5001
(402) 294-4087

Major Ross Miller/Mr. Jim Williams
AFCEE/EST
Brooks Air Force Base, TX 78235-5000
(210) 536-4331

Mr. Doug Downey/Mr. Jim Walters
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290
(303) 831-8100
Fax (303) 831-8208

8.0 REFERENCES

Engineering-Science, Inc., 1992. *Project Management Plan AFCEE Bioventing Pilot Tests: Appendix D - Field Sampling Plan.* p.D-7.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* January.

Woodward-Clyde Consultants, 1992. Installation Restoration Program Step 6 - Initial Site Assessment, Offutt Air Force Base, Omaha, Nebraska.

PART II

DRAFT

INTERIM PIOLT TEST RESULTS REPORT BUILDING 30 AND POL STORAGE AREA OFFUTT AFB, NEBRASKA

Prepared for:

Air Force Center for Environmental Excellence

Brooks AFB, Texas

and

Headquarters 55th Air Combat Command (ACC)

Offutt AFB, Nebraska

July 1993

Prepared by:

Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

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PART II

DRAFT
INTERIM PILOT TEST RESULTS REPORT
FOR BUILDING 30 AND POL STORAGE AREA
OFFUTT AFB, NEBRASKA

Initial bioventing pilot tests were completed by Engineering-Science, Inc. (ES) at Building 30 and the Petroleum Oils, and Lubricants (POL) storage area at Offutt Air Force Base (AFB), Nebraska during the period of April 26 through May 8, 1993. The purpose of this Part II report is to describe the results of the initial pilot tests at the Building 30 and POL storage area sites and to make specific recommendations for extended testing to determine the long-term impact of bioventing on site contaminants. Descriptions of the history, geology, and contamination at Building 30 and POL storage area sites are contained in Part I, the Bioventing Pilot Test Work Plan.

1.0 PILOT TEST DESIGN AND CONSTRUCTION

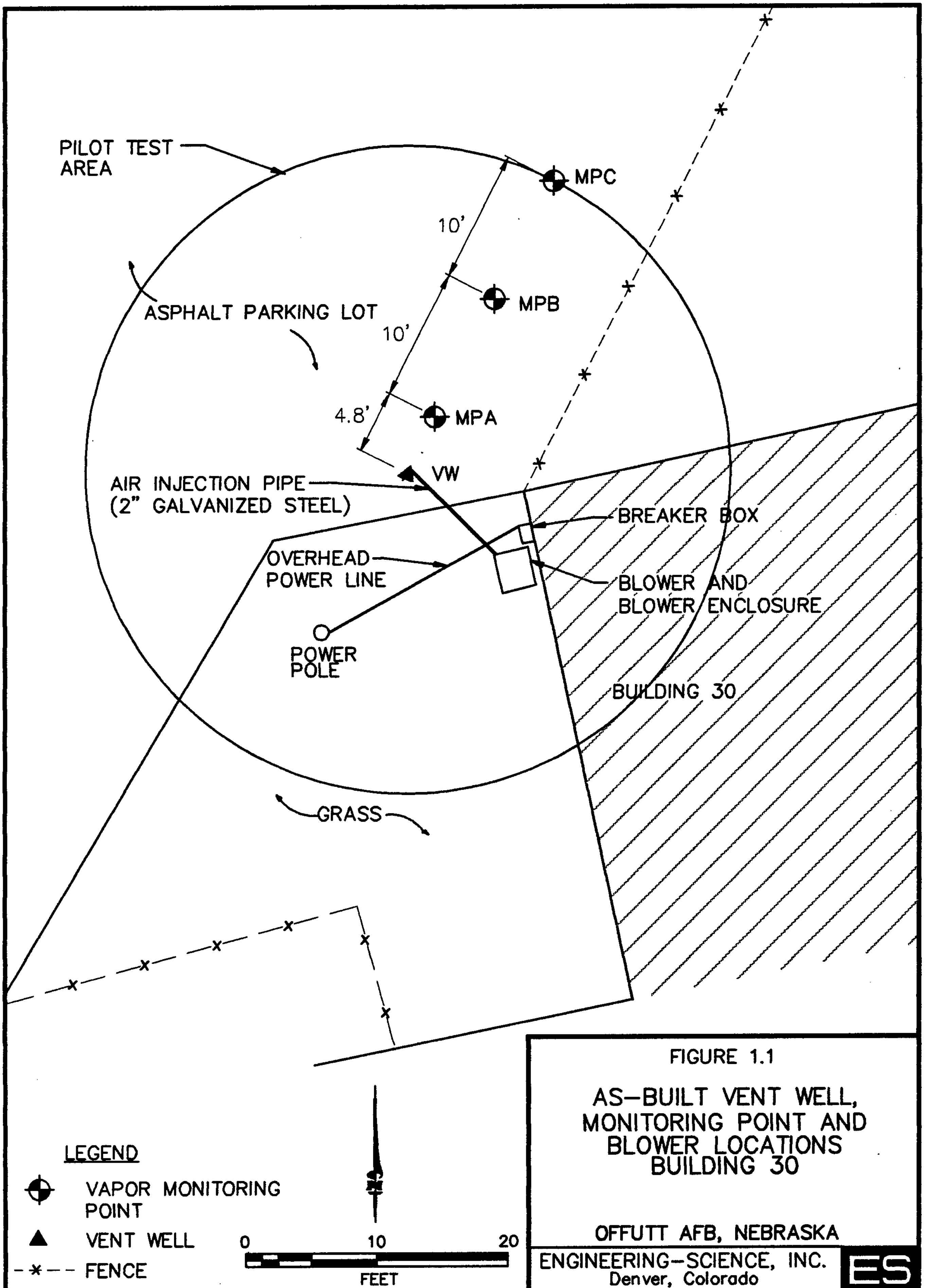
Installation of an air injection vent well (VW) and three vapor monitoring points (MPs) at each site took place on April 26 through April 30, 1993. Drilling services were provided by Layne Western, Inc. of Omaha, Nebraska, and well installation and soil sampling was directed by Mr. Jim Walters, the ES site manager. The following sections describe the final design and installation of the bioventing systems at each site.

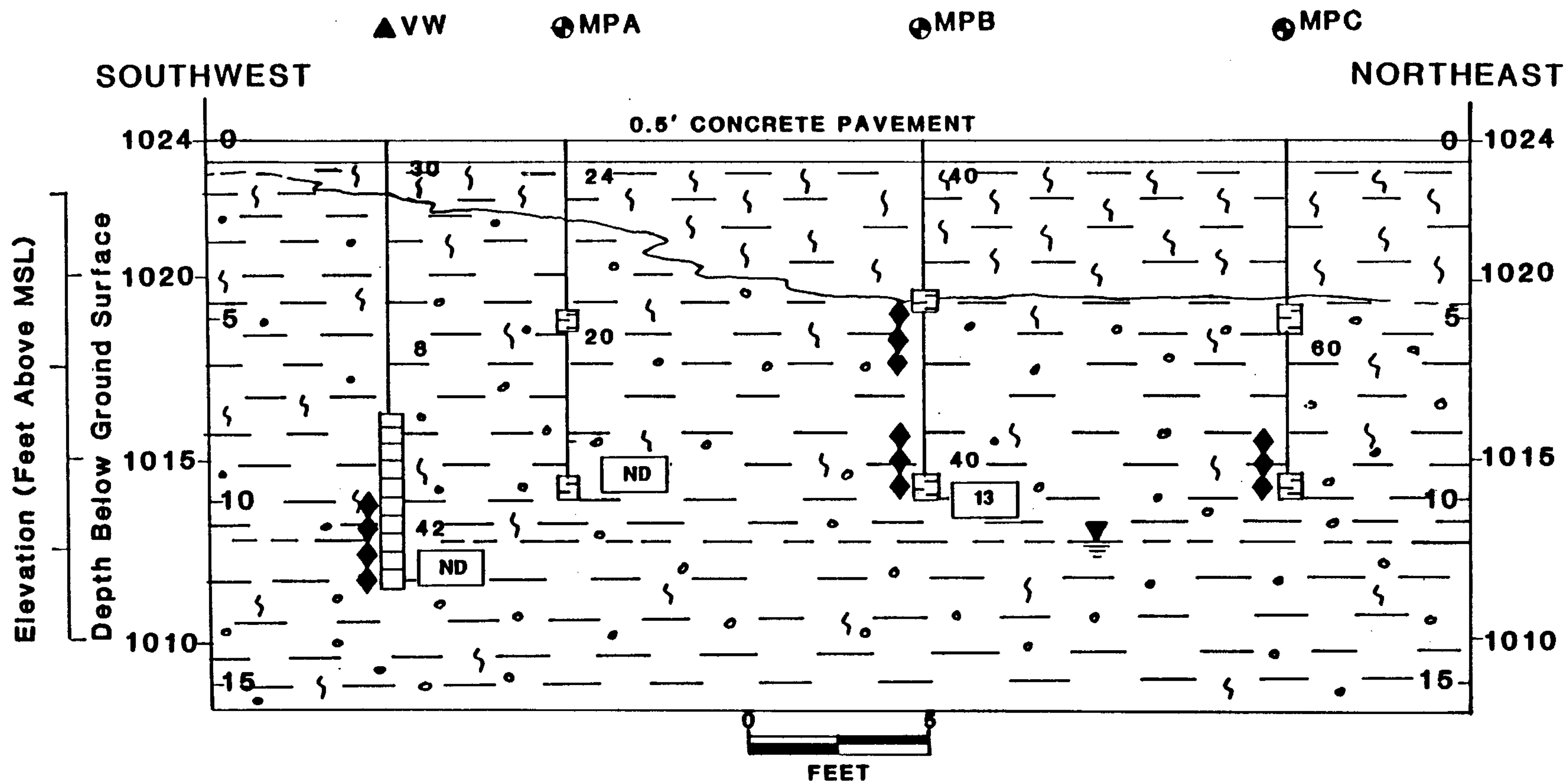
1.1 Building 30

One VW, three MPs (MPA, MPB, and MPC), and a blower unit were installed at the Building 30 site. The final locations of the VW, MPs, and blower unit are as proposed in the Part I work plan. Figures 1.1 and 1.2, respectively, depict the locations of and hydrogeologic cross section for the VW and MPs completed at the site. Boring logs for the MPs and VW are included in Appendix A. The background MP for this site was the existing groundwater monitoring well HF5-MW2, which was screened to 1.5 feet above the current groundwater surface.

1.1.1 Air Injection Vent Well

The air injection VW was installed following procedures described in the Air Force Center for Environmental Excellence (AFCEE) bioventing protocol document (Hinchee et al., 1992). Figure 1.3 shows construction details for the VW.


PILOT TEST AREA
MPC
10'
MPB
ASPHALT PARKING LOT
10'
4.8'
MPA
VW
AIR INJECTION PIPE (2" GALVANIZED STEEL)
BREAKER BOX
OVERHEAD POWER LINE
BLOWER AND BLOWER ENCLOSURE
POWER POLE
BUILDING 30
GRASS
LEGEND
VAPOR MONITORING POINT
VENT WELL
FENCE
0
10
20
FEET
FIGURE 1.1
AS-BUILT VENT WELL, MONITORING POINT AND BLOWER LOCATIONS BUILDING 30
OFFUTT AFB, NEBRASKA
ENGINEERING-SCIENCE, INC.
Denver, Colorado
ES



LITHOLOGIC DESCRIPTION

SILT WITH CLAY

CLAY WITH SILT AND PEBBLES

LEGEND

MPA	MONITORING POINT		GROUNDWATER ELEVATION
VW	INJECTION VENT WELL		GEOLOGIC CONTACT, DASHED WHERE INFERRED
60	FIELD SCREENING RESULTS FOR TOTAL VOLATILE HYDROCARBONS (ppmv)		MONITORING POINT SCREENED INTERVAL
13	LABORATORY RESULTS FOR SOIL TOTAL PETROLEUM HYDROCARBONS (mg/kg)		SCREENED WELL INTERVAL
	FUEL ODOR DETECTED DURING DRILLING		
ND	NOT DETECTED	M.S.L.	MEAN SEA LEVEL

FIGURE 1.2

HYDROGEOLOGIC CROSS SECTION BUILDING 30

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

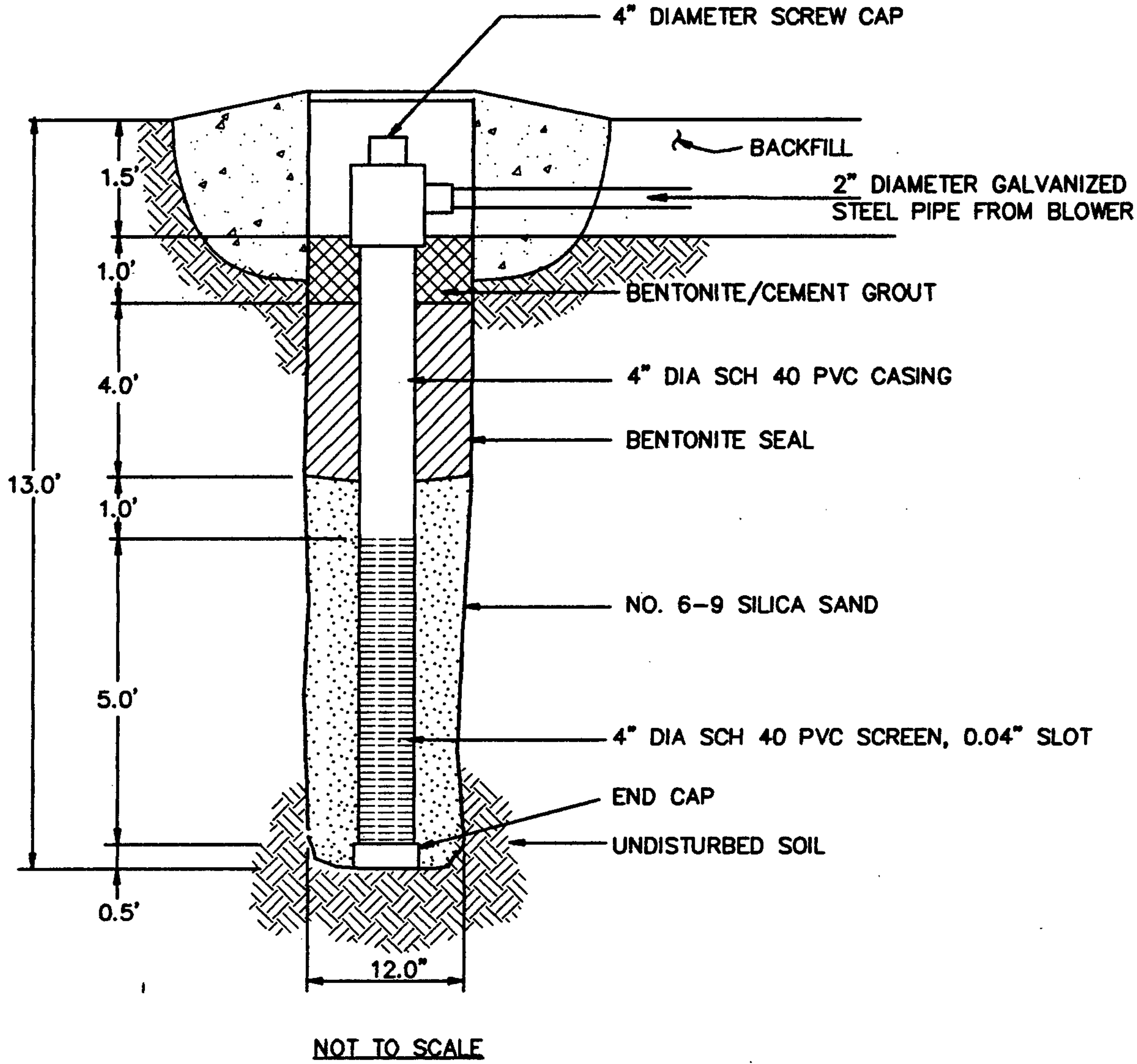


FIGURE 1.3

AS-BUILT INJECTION/ VENT WELL CONSTRUCTION DETAIL BUILDING 30

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

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The VW was installed in contaminated soils with the screened interval extending from 7.5 to 12.5 feet below ground surface (bgs). The groundwater surface at this site was 10.8 feet bgs during the pilot test. The VW was constructed using 4-inch-diameter, schedule 40 polyvinyl chloride (PVC) casing, with 5 feet of 0.04-inch slotted PVC screen. The annular space between the well casing and borehole was filled with 6-9 silica sand from the bottom of the borehole to approximately 1 foot above the well screen. One foot of bentonite pellets and 4 feet of bentonite chips were placed above the sand, hydrated in place, and overlaid with a 1-foot bentonite/cement grout seal and a concrete seal to the existing concrete pavement surface. The top of the well was completed with a 4-inch-diameter PVC tee with a screw cap.

1.1.2 Monitoring Points

The MP screens were installed at 5- and 9.5-foot depths with the exception of MPB, in which the shallow screen was placed at 4.5 feet bgs. The three MPs (MPA, MPB, and MPC) at this site were constructed as shown in Figure 1.4. Each was constructed using 6-inch sections of 1-inch-diameter PVC well screen with 0.25-inch PVC riser pipes extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was completed with a flush-mounted metal well protector set in concrete. Thermocouples were installed at the 5- and 9.5-foot depths at MPA to measure soil temperature variations.

The existing groundwater monitoring well HF5-MW2 was utilized as a background MP. This well is located approximately 1.2 miles southeast of the Building 30 pilot test area, and is screened at approximately 5.0 to 15.0 feet bgs.

1.1.3 Blower Unit

A 3-horsepower Roots® positive-displacement blower was used for the initial pilot test and a 1-horsepower Gast® regenerative blower unit was installed at the site for the extended pilot test. The initial pilot test blower and the extended test blower were energized by 230-volt, single-phase, 30-amp power from a newly installed breaker adjacent to the blower enclosure. The 1-horsepower extended pilot test blower was configured to inject approximately 10 standard cubic feet per minute (scfm) for the extended pilot test. The configuration, instrumentation, and specifications for the extended pilot test units are shown on Figure 3.5 of the Work Plan (Part I) and Figure 1.5, respectively. Prior to departing from the site, ES engineers provided an operations and maintenance (O&M) briefing instructions and blower maintenance manual to base personnel. A copy of the instructions is provided in Appendix B.

1.2 POL Storage Area

One VW, three MPs (MPA, MPB, and MPC), and a blower unit were installed at the POL storage area. Figures 1.6 and 1.7, respectively, depict the locations of and hydrogeologic cross section for the VW and MPs completed at the site. Boring logs for the MPs and VW are included in Appendix A. The background MP for this site

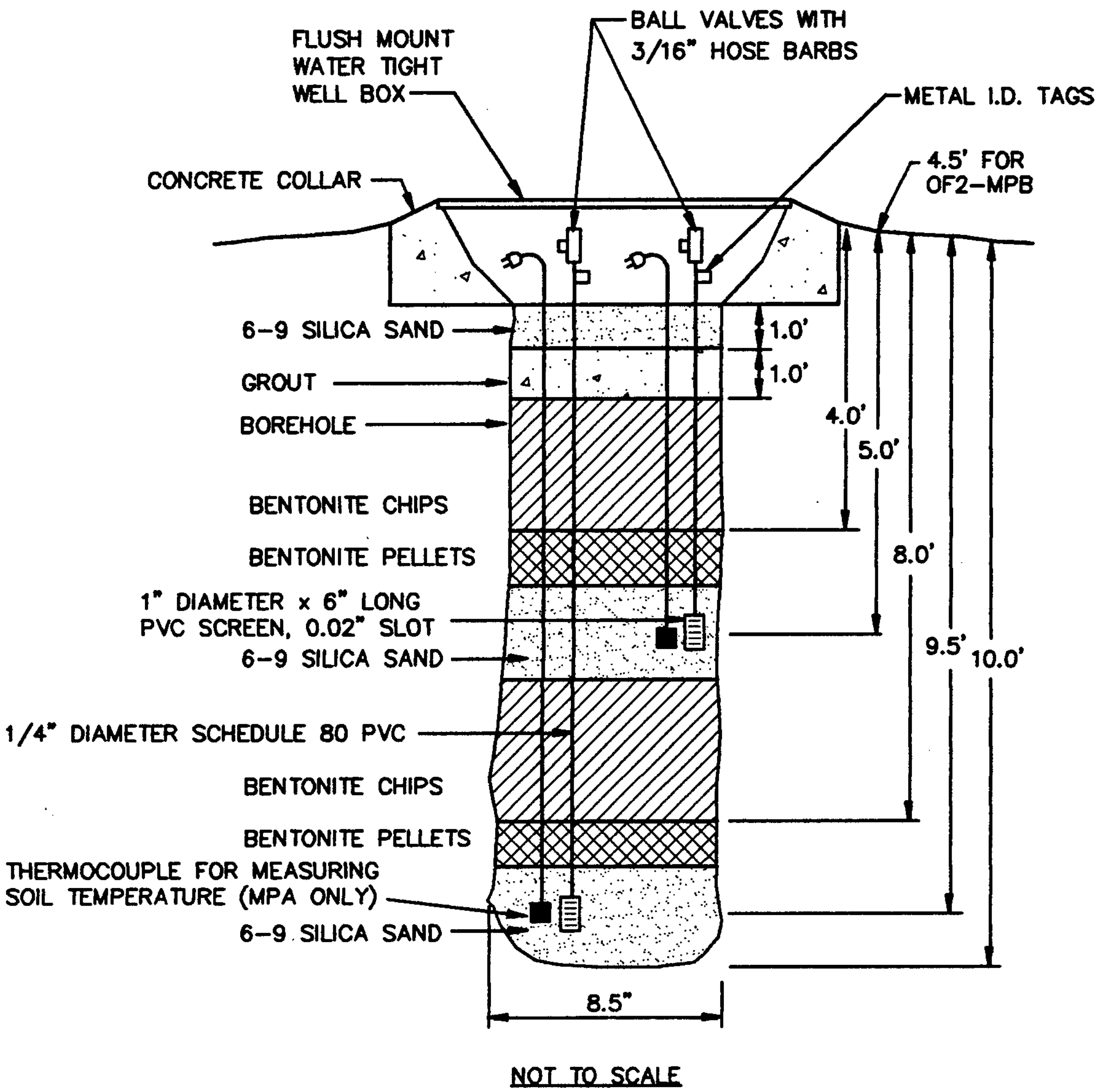

FIGURE 1.4

AS-BUILT
MONITORING POINT
CONSTRUCTION DETAIL
BUILDING 30

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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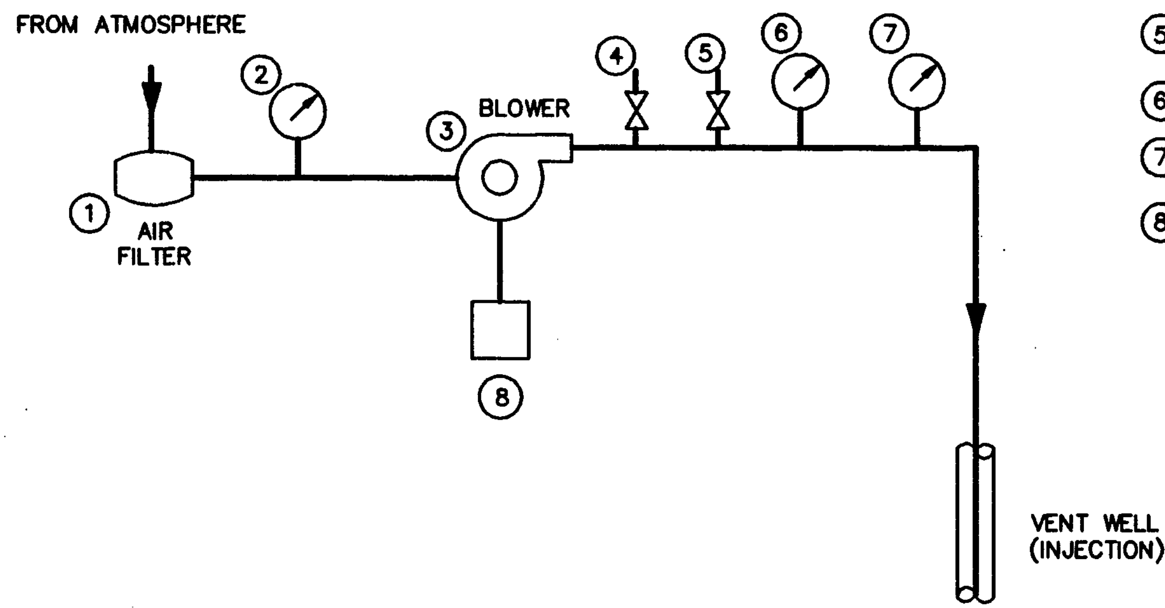

LEGEND

1. INLET AIR FILTER – SOLBERG® F-18P-150
2. VACUUM GAUGE (in H_2O)
3. 1-HP BLOWER – GAST® R4110N-50
4. AUTOMATIC PRESSURE RELIEF VALVE
5. MANUAL PRESSURE RELIEF (BLEED) VALVE 1 1/2" GATE
6. PRESSURE GAUGE (in H_2O)
7. TEMPERATURE GAUGE (°F)
8. BREAKER BOX – 230V/SINGLE PHASE/30 AMP

FIGURE 1.5

AS- BUILT
EXTENDED PILOT TEST BLOWER
SYSTEM FOR AIR INJECTION
BUILDING 30

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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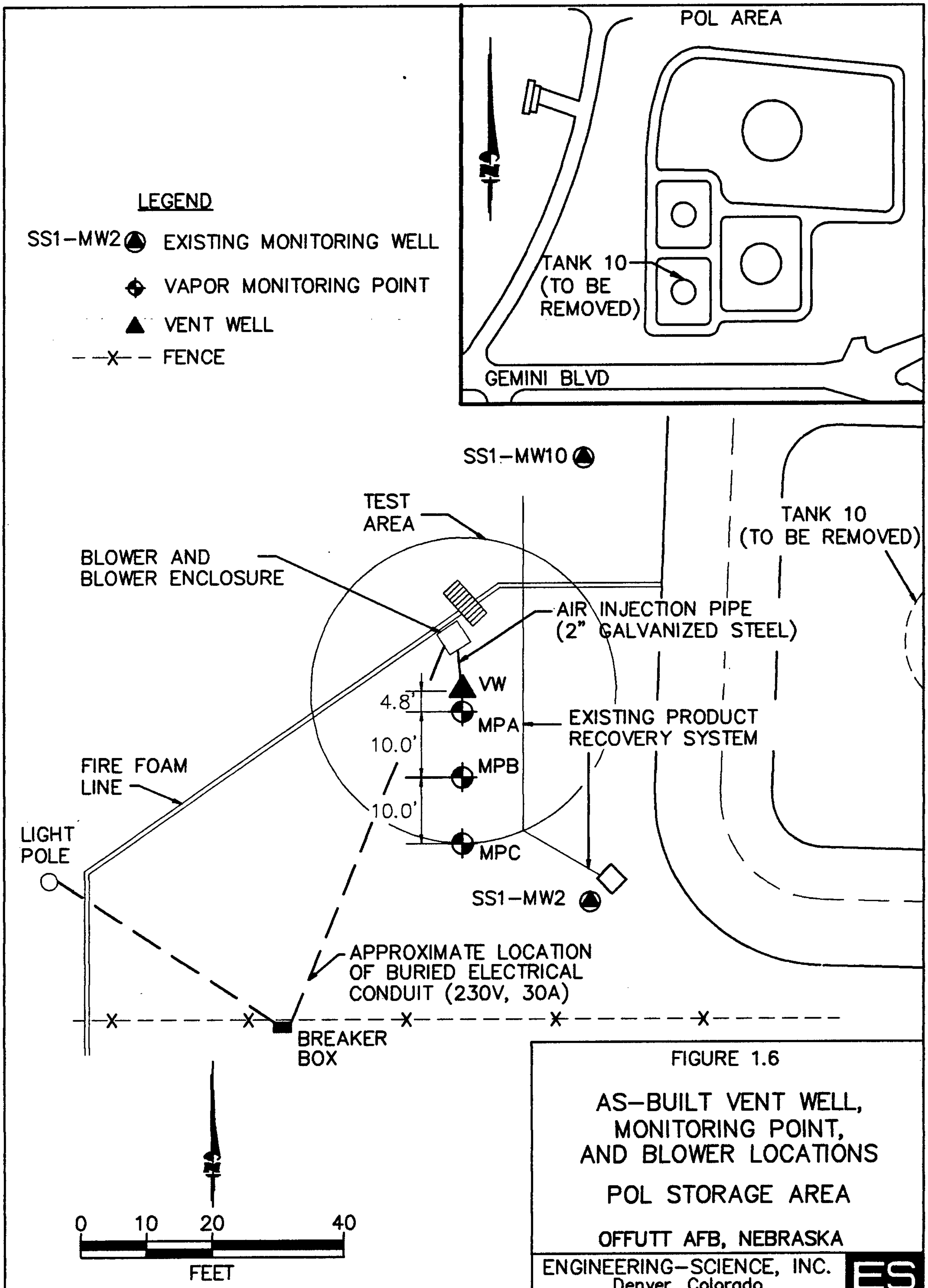

FIGURE 1.6

AS-BUILT VENT WELL, MONITORING POINT, AND BLOWER LOCATIONS

POL STORAGE AREA

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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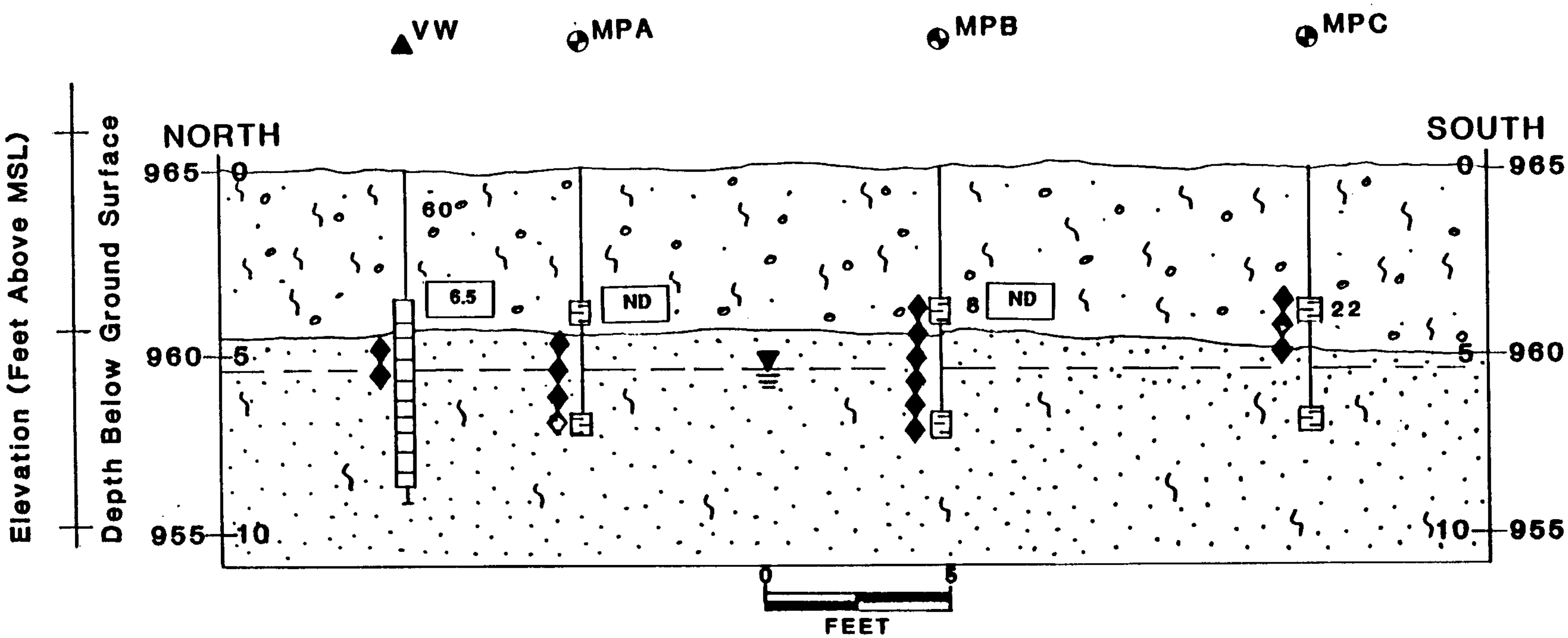


LITHOLOGIC DESCRIPTION

SILT WITH SAND AND PEBBLES

SAND WITH SILT

LEGEND

MPA MONITORING POINT

VW INJECTION VENT WELL

60 FIELD SCREENING RESULTS FOR TOTAL VOLATILE HYDROCARBONS (ppmv)

6.5 LABORATORY RESULTS FOR SOIL TOTAL PETROLEUM HYDROCARBONS (mg/kg)

FUEL ODOR DETECTED DURING DRILLING

ND NOT DETECTED

GROUNDWATER ELEVATION

GEOLOGIC CONTACT, DASHED WHERE INFERRED

MONITORING POINT SCREENED INTERVAL

SCREENED WELL INTERVAL

M.S.L. MEAN SEA LEVEL

FIGURE 1.7

HYDROGEOLOGIC CROSS SECTION POL STORAGE AREA

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

ES

was the existing groundwater monitoring well HF5-MW2, located approximately 0.6 mile northeast of the POL storage area.

1.2.1 Air Injection Vent Well

The air injection VW was installed following procedures described in the AFCEE bioventing protocol document (Hinchee et al., 1992). Figure 1.8 shows construction details for the VW. The VW was installed in contaminated soils with the screened interval extending from 3.5 to 8.5 feet bgs. The groundwater surface at this site was 5.0 feet bgs during the pilot test, however the depth to water may vary depending on the pumping rates of adjacent product recovery wells. The VW was constructed using 4-inch-diameter, schedule 40 PVC casing, with 5 feet of 0.04-inch slotted PVC screen. The annular space between the well casing and borehole was filled with 6-9 silica sand from the bottom of the borehole to approximately 1 foot above the well screen. One and one half feet of bentonite pellets were placed above the sand, hydrated in place, and overlaid with a 0.5-foot bentonite/cement grout seal, and a concrete seal to the existing natural grass surface. The top of the well was completed with a 4-inch-diameter PVC tee with a screw cap.

1.2.2 Monitoring Points

The MP screens were installed at 4- and 7-foot depths. The three MPs (MPA, MPB, and MPC) at this site were constructed as shown in Figure 1.9. Each was constructed using 6-inch sections of 1-inch-diameter PVC well screen and 0.25-inch PVC riser pipes extending to the ground surface. At the top of each riser, a ball valve and a 3/16-inch hose barb were installed. The top of each MP was completed with a flush-mounted metal well protector set in concrete. Thermocouples were installed at the 4- and 7-foot depths at MPA to measure soil temperature variations.

1.2.3 Blower Unit

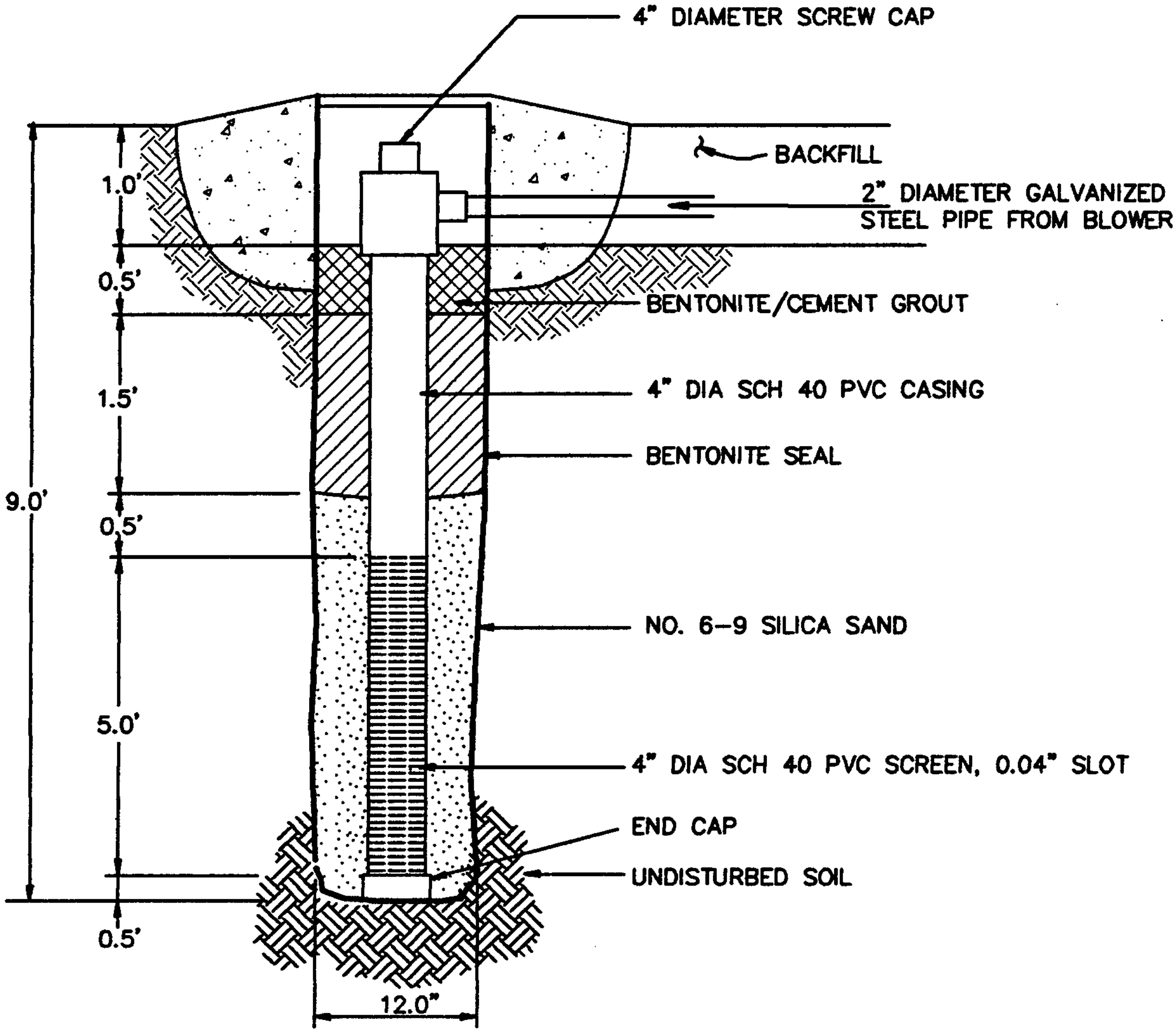
A 3-horsepower Roots® positive-displacement blower was used for the initial pilot test, and a 1-horsepower Gast® regenerative blower unit was installed at the site for the extended pilot test. The initial pilot test blower and the extended test blower were energized by 230-volt, single-phase, 30-amp power from a newly installed breaker adjacent to the blower enclosure. The blower was configured to inject approximately 10 scfm for the extended pilot test. The configuration, instrumentation, and specifications for the extended pilot test unit is shown on Figure 1.10. Prior to departing from the site, ES engineers provided an O&M briefing checklist and blower maintenance manual to plant personnel. A copy of the checklist is provided in Appendix B.

2.0 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

2.1 Building 30

2.1.1 Sampling Results

Soils at this site consist of silt and clay fill, underlain by glacially derived silts and clays. The general soil profile consists of fill material in the upper 5 feet and silt with clay from approximately 5 to 13 feet bgs (Figure 2.1). Groundwater occurred at 10.8 feet bgs in the VW. With the exception of the location of the blower



NOT TO SCALE

FIGURE 1.8

AS-BUILT INJECTION/
VENT WELL
CONSTRUCTION DETAIL
POL STORAGE AREA

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado

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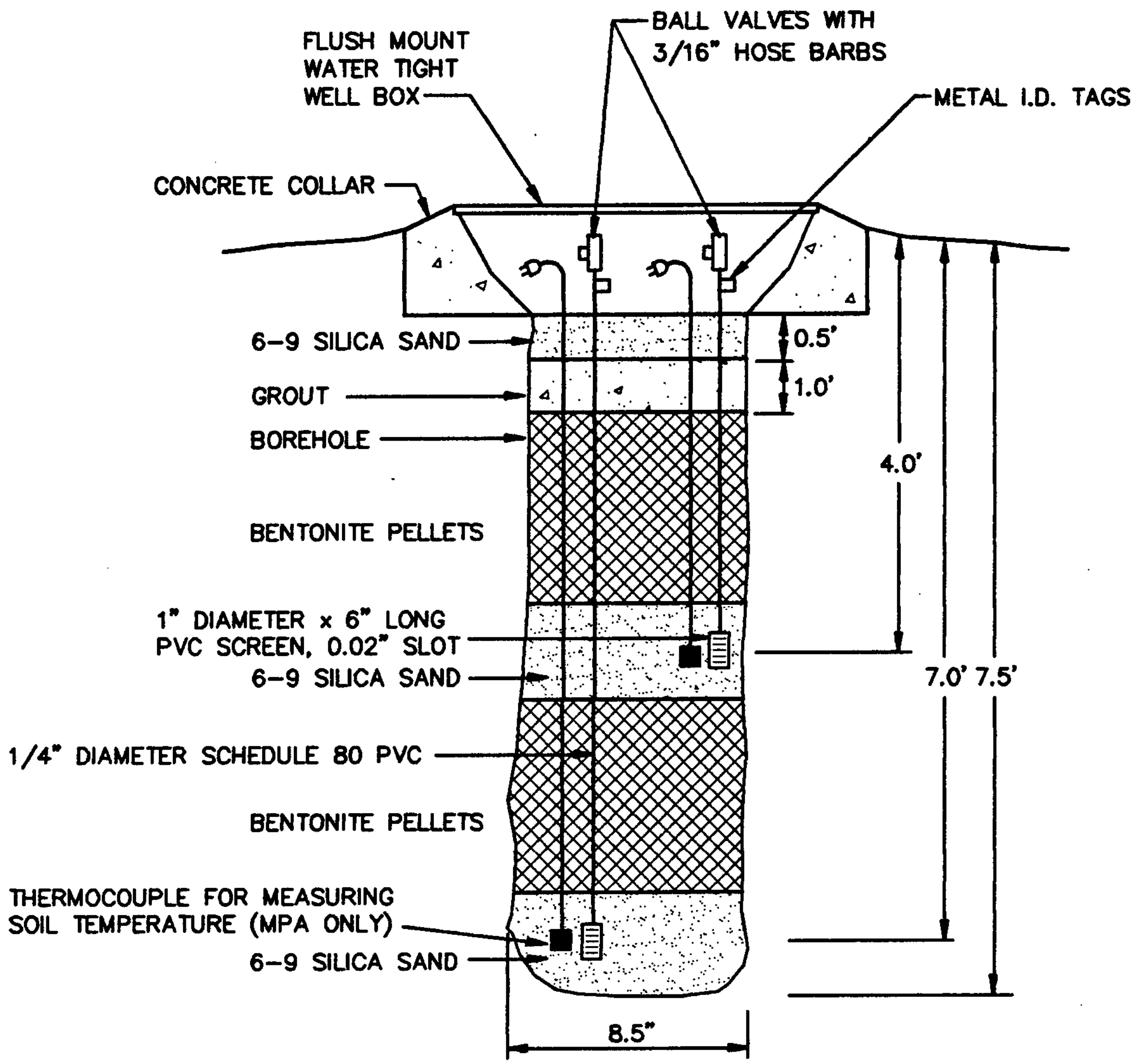


NOT TO SCALE

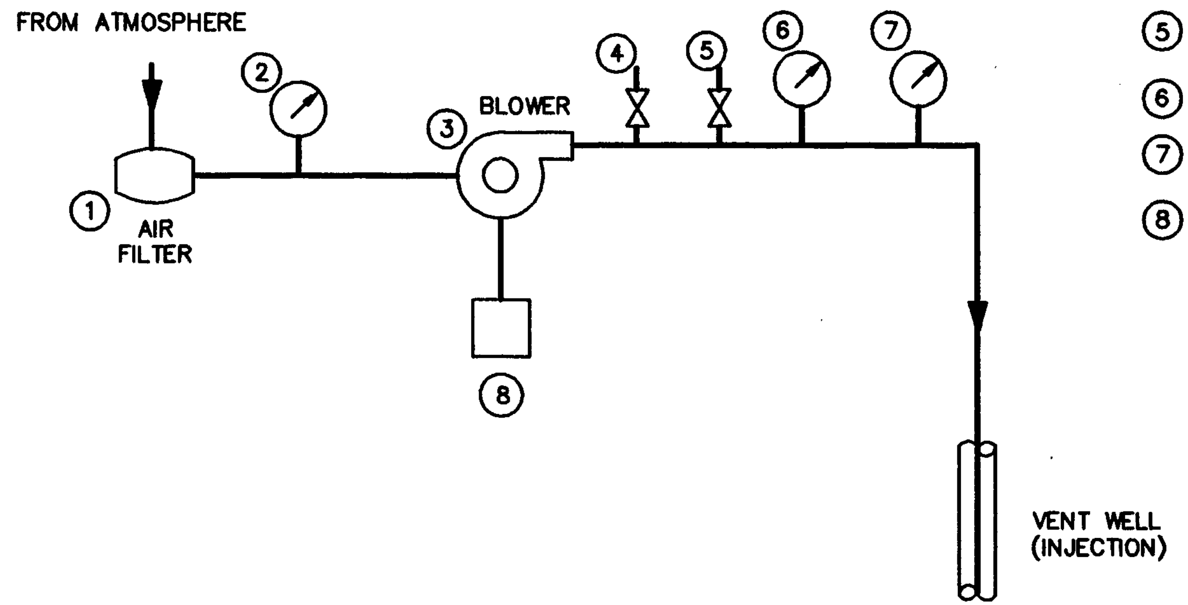
FIGURE 1.9

TYPICAL AS-BUILT MONITORING POINT CONSTRUCTION DETAIL

POL STORAGE AREA

OFFUTT AFB, NEBRASKA

ENGINEERING-SCIENCE, INC.
Denver, Colorado



LEGEND

1. INLET AIR FILTER – SOLBERG® F–18P–150
2. VACUUM GAUGE (in H_2O)
3. 1–HP BLOWER – GAST® R4110N–50
4. AUTOMATIC PRESSURE RELIEF VALVE
5. MANUAL PRESSURE RELIEF (BLEED) VALVE 1 1/2" GATE
6. PRESSURE GAUGE (in H_2O)
7. TEMPERATURE GAUGE (°F)
8. BREAKER BOX – 230V/SINGLE PHASE/30 AMP

FIGURE 1.10

AS– BUILT
EXTENDED PILOT TEST BLOWER SYSTEM FOR AIR INJECTION
POL STORAGE AREA

OFFUTT AFB, NEBRASKA

ENGINEERING–SCIENCE, INC.
Denver, Colorado

ES

93DN0606, 07/27/93 at 14:55

enclosure, the entire site is covered with approximately 6 inches of concrete pavement. Boring logs for the MPs and VW are included in Appendix A.

Hydrocarbon contamination at this site appears to be confined within a zone extending from about 0 to 8 feet above the groundwater surface. Contaminated soils were identified based on odor and volatile organic compound (VOC) field screening results. Contaminated soils were encountered in the VW and all MP boreholes, with the greatest contamination occurring in MPC. Soils at these locations had a strong hydrocarbon odor (Figure 1.2).

Soil samples for laboratory analysis were collected from 24-inch split-spoon samplers. Brass liners were not used for sample collection due to liner incompatibility with the split-spoon samplers provided by the drilling subcontractor. Soil samples were screened for VOCs using a total hydrocarbon analyzer to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from a depth of 10 to 12 feet bgs from the VW, and from a depth of 8 to 10 feet bgs from MPA and MPB. Soil gas samples were collected by extracting soil gas from the completed VW, and at 9.5 feet bgs from MPA and MPB.

Soil samples were shipped via Federal Express® to the Pace, Inc. laboratory located in Novato, California for chemical and physical analysis. Soil samples were analyzed for total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene and xylenes (BTEX); iron; alkalinity; total Kjeldahl nitrogen (TKN); and several physical parameters. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Rancho Cordova, California for total volatile hydrocarbon (TVH) and BTEX analysis. The results of these analyses are provided in Table 2.1.

Results for TRPH in the soil samples appear to be lower than would typically be expected based on field screening results and observations made during drilling (strong fuel odor and staining). The lower-than-expected TRPH analytical results may be due to matrix interference or the fact that the Environmental Protection Agency (EPA) Method 418.1, specified by AFCEE, is not particularly accurate for volatile AVGAS spilled at the site.

2.1.2 Exceptions To Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete treatability tests at site Building 30. The exception to sampling protocol was the collection of samples for TRPH and BTEX analyses into glass jars rather than the brass tubes specified. This was done as a result of driller equipment incompatibility with the brass liners.

2.2 POL Storage Area

2.2.1 Sampling Results

Soils at this site consist primarily of silt with clay fill overlying sand with silt and pebbles (Figure 1.7). Groundwater occurred at 5 feet bgs in the VW and MPC

TABLE 2.1

SOIL AND SOIL GAS ANALYTICAL RESULTS

BUILDING 30

OFFUTT AFB, NEBRASKA

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
Soil Gas Hydrocarbons	OF2-VW-10	MPB-9.5	MPC-9.5
TVH (ppmv)	1,500	15,000	8,000
Benzene (ppmv)	ND[b]	ND	ND
Toluene (ppmv)	ND	ND	ND
Ethylbenzene (ppmv)	ND	ND	ND
Xylenes (ppmv)	0.56	3.2	0.91
Soil Hydrocarbons	OF2-VW-10	MPA-8	MPB-8
TRPH (mg/kg)	ND	ND	13
Benzene (mg/kg)	ND	ND	ND
Toluene (mg/kg)	0.0055	0.00074	0.0024
Ethylbenzene (mg/kg)	ND	ND	ND
Xylenes (mg/kg)	0.037	0.0023	0.0028
Soil Inorganics	OF2-VW-10	MPA-8	MPB-8
Iron (mg/kg)	12,100	16,700	12,400
Alkalinity (mg/kg as $CaCO_3$)	950	2,500	1,380
pH (units)	8	8	10
TKN (mg/kg)	310	240	210
Phosphates (mg/kg)	650	650	730
Soil Physical Parameters	OF2-VW-10	MPA-8	MPB-8
Moisture (% wt.)	25	25	23
Gravel (%)	0	0	0
Sand (%)	1.2	2.0	7.6
Silt (%)	75.0	77.3	71.8
Clay (%)	23.8	20.6	20.6

a/ mg/kg=milligrams per kilogram, ppmv=parts per million, volume per volume; $CaCO_3$=Calcium carbonate; TKN=total Kjeldahl nitrogen; TVH=total volatile hydrocarbons; TRPH=total recoverable petroleum hydrocarbons.

b/ ND=not detected.

boreholes. The ground surface of this site is covered with grass. Boring logs for the MPs and VW are included in Appendix A.

Hydrocarbon contamination at this site was detected within a zone extending from about 0 to 3 feet above the groundwater surface. Recent rains had elevated local groundwater levels to a seasonal high. Contaminated soils were identified based on odor and VOC field screening results. Contaminated soils were encountered in the VW and all MP boreholes, with the greatest contamination in the borehole for the VW. Soils at these locations had a strong hydrocarbon odor.

Soil samples for laboratory analysis were collected from 24-inch split-spoon samplers. Brass liners were not used for sample collection due to liner incompatibility with split spoons provided by the drilling subcontractor. Soil samples were screened for VOCs using a total hydrocarbon analyzer to determine the presence of contamination and to select soil samples for laboratory analysis. Soil samples for laboratory analysis were collected from a depth of 3 to 5 feet from the VW, MPA, and MPB. Soil gas samples were collected by extracting soil gas from the completed VW, and from a depth of 4 feet from MPC.

Soil samples were shipped via Federal Express® to the Pace, Inc. laboratory located in Novato, California for chemical and physical analysis. Soil samples from the MPs were analyzed for TRPH, BTEX, iron, alkalinity, TKN, and several physical parameters. Soil gas samples were shipped via Federal Express® to Air Toxics, Inc. in Rancho Cordova, California for TVH and BTEX analysis. The results of these analyses are provided in Table 2.2. As discussed in Section 2.1.1, the TRPH results appear to be low, possibly as the result of matrix interference.

2.2.2 Exceptions To Test Protocol Document Procedures

Procedures described in the protocol document (Hinchee et al., 1992) were used to complete treatability tests at the POL storage area. The exception to sampling protocol was the collection of samples for TRPH and BTEX analyses into glass jars rather than the brass tubes specified. This was done as a result of driller equipment incompatibility. In addition, the deeper of the two screened MP intervals (installed at 7 feet bgs) were not utilized for the pilot respiration tests, as they were below the level of the seasonal groundwater table. These screened interval should be available for monitoring as the groundwater table drops.

3.0 PILOT TEST RESULTS

3.1 Building 30

3.1.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs were purged until oxygen levels had stabilized, and initial oxygen, carbon dioxide, and TVH concentrations were then sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Soil gas oxygen levels at the VW were 5.5 percent. Oxygen levels at MPA were 15.3 and 6.0 percent for the screened interval placed at 5 feet bgs and 9.5 bgs, respectively. Oxygen levels at MPB were 0 percent for the screened interval placed at 9.5 feet bgs. Oxygen concentrations were not obtainable

TABLE 2.2
SOIL AND SOIL GAS ANALYTICAL RESULTS
POL STORAGE AREA
OFFUTT AFB, NEBRASKA

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)		
Soil Gas Hydrocarbons	OF3-VW[b]	MPC-4	
TVH (ppmv)	26,000	1,000	
Benzene (ppmv)	130	3.6	
Toluene (ppmv)	21	1.9	
Ethylbenzene (ppmv)	7.2	0.90	
Xylenes (ppmv)	18	2.0	
Soil Hydrocarbons	OF3-VW-3	MPA-3	MPB-3
TRPH (mg/kg)	6.5	ND	ND
Benzene (mg/kg)	.0041	0.0075	0.0011
Toluene (mg/kg)	ND[c]	0.0022	ND
Ethylbenzene (mg/kg)	ND	0.053	0.0049
Xylenes (mg/kg)	ND	0.082	0.002
Soil Inorganics	OF3-VW-3	MPA-3	MPB-3
Iron (mg/kg)	10,200	9,550	9,730
Alkalinity (mg/kg as $CaCO_3$)	460	510	440
pH (units)	7.8	7.9	7.9
TKN (mg/kg)	650	860	730
Phosphates (mg/kg)	600	600	590
Soil Physical Parameters	OF3-VW-3	MPA-3	MPB-3
Moisture (% wt.)	18	20	19
Gravel (%)	0	0	0
Sand (%)	31.6	26.3	18.3
Silt (%)	49.4	64.3	67.6
Clay (%)	19.0	9.4	14.1

a/ mg/kg=milligrams per kilogram, ppmv=parts per million, volume per volume; $CaCO_3$=Calcium carbonate; TKN=total Kjeldahl nitrogen; TVH=total volatile hydrocarbons; TRPH=total recoverable petroleum hydrocarbons.

b/ Average value of sample and laboratory duplicate results.

c/ ND = not detected.

from the screened interval placed at 4.5 feet bgs at MPB. Soil around this screened interval may be saturated, or the screen may have become clogged during construction. Oxygen levels at MPC-5 were 1.5 percent and 0 percent at MPC-9.5. Table 3.1 summarizes the initial soil gas chemistry.

3.1.2 Air Permeability

An air permeability test was conducted according to protocol document procedures. Air was injected into the VW for 19 hours at a rate of approximately 10 scfm and an average pressure of 81 inches of water. The injection air pressure was maintained at 81 inches of water throughout the test by adjusting the flow rate. The maximum pressure response at each MP is listed in Table 3.2. The pressure measured at the MPs gradually increased at a regular rate throughout the period of air injection except for the 5 foot interval at MPA, which showed no pressure response for the duration of the injection. A radius of pressure influence of at least 25 feet was observed; however, there appear to be zones of low permeability where air flow was restricted during initial testing. Experience has shown that air flow and oxygen diffusion can, over time, influence these soils. Additional testing after 6 months of air injection will determine long term oxygen transport. As discussed in the protocol document, the dynamic method of determining soil gas permeability that is coded in the HyperVentilate® model is only appropriate for soils which reach steady-state in a time greater than 10 minutes In this pilot test, steady-state conditions were reached approximately 30 minutes into the test, and the HyperVentilate® model was used except for MPC-5. Soil gas permeability for MPC-5 was calculated by the steady-state equation. The resulting calculated permeabilities are listed in Table 3.2.

3.1.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.3 presents the change in soil gas oxygen levels that occurred during the 19-hour period of injection using the extended pilot test blower unit. Based on measured pressure response, which is an indicator of long-term oxygen transport, it is anticipated that the radius of oxygen influence for a long-term bioventing system will exceed 25 feet at all depths using a regenerative blower. Monitoring during the extended pilot test at this site will better define the effective treatment radius.

3.1.4 In Situ Respiration Rates

The *in situ* respiration test was performed by injecting a mixture of air (oxygen) and approximately 2 percent helium (inert tracer gas) into the VW and three MP screened intervals (MPB-9.5, MPC-5, and MPC-9.5) for a 20-hour period. Oxygen loss and other changes in soil gas composition over time were then measured at these intervals and all other MP screened intervals. Oxygen, TVH, carbon dioxide, and helium were measured for a period of approximately 48 hours following air

TABLE 3.1
INITIAL SOIL GAS CHEMISTRY
BUILDING. 30
OFFUTT AFB, NEBRASKA

Sample Location	Depth (ft)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)[a]	Lab TVH (ppmv)[b]	Soil TRPH (mg/kg)[c]
VW	7.5-12.5	5.5	4.8	1,550	1,500	ND[d]
MPA	5	15.3	0.5	110	NS	NS[e]
MPB	4.5	NS	NS	NS	NS	NS
MPC	5	1.5	4.8	4,000	NS	NS
MPA	9.5	6.0	0.9	1,200	NS	ND
MPB	9.5	0.0	4.7	9,600	15,000	13
MPC	9.5	0.0	4.3	4,400	8,000	NS

a/ Field screening results, in parts per million, volume per volume (ppmv).
b/ Laboratory results.
c/ Laboratory soil results, in milligrams per kilogram (mg/kg).
d/ ND = not detected.
e/ NS = not sampled.

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TABLE 3.2

MAXIMUM PRESSURE RESPONSE AND CALCULATED PERMEABILITY
AIR PERMEABILITY TEST
BUILDING 30
OFFUTT AFB, NEBRASKA

Monitoring Point	Distance from VW (feet)	Depth (feet)	Maximum Pressure Response (inches H_2O)	Calculated Air Permeability (Darcys)[a/]
A	5	5	0.0	NS[b/]
B	15	4.5	0.26	1.1
C	25	5	0.24	6.5[c/]
A	5	9.5	0.42	0.2
B	15	9.5	0.36	14
C	25	9.5	0.25	114

a/ Calculated using Method 2 of the HyperVentilate® program.
b/ Not sampled.
c/ Calculated using steady-state equation.

TABLE 3.3
INFLUENCE OF AIR INJECTION AT VENT WELL
ON MONITORING POINT OXYGEN LEVELS
BUILDING 30
OFFUTT AFB, NEBRASKA

MP	Distance From VW (ft)	Depth(ft)	Initial O_2(%)	Final O_2(%) Long-term System[a/]
A	5	5	15.3	14.9
B	15	4.5	NS[b/]	NS
C	25	5	1.5	2.7
A	5	9.5	6.0	NS
B	10	9.5	0.0	8.2
C	20	9.5	0.0	2.2

a/ Reading taken after approximately 19 hours of injection using long-term blower system.
b/ Not sampled due to soil impermeability.

injection. The measured oxygen losses were then used to calculate biological oxygen utilization rates. The results of *in situ* respiration testing for selected MP intervals at this site are presented in Figures 3.1 through 3.3. The remainder of the results are presented in Appendix A. Table 3.4 provides a summary of the oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining the effectiveness of the bentonite seals between MP screened intervals. Figures 3.1 through 3.3 compare oxygen utilization and helium retention. Because the observed helium loss was negligible, and because helium will diffuse approximately three times faster than oxygen due to oxygen's greater molecular weight, the measured oxygen loss is the result of bacterial respiration and not due to faulty MP construction.

Results from this respiration test indicate that significant soil hydrocarbon contamination existed at all screened intervals sampled except MPA-5, MPA-9.5, and MPB-4.5 (Table 3.1). Representative soil gas samples could not be collected from MPA-5, MPA-9.5, and MPB-4.5 because of very low soil permeability. Initial soil gas oxygen concentrations ranged from 0 percent at MPB-9.5 and MPC-9.5 to 15.3 percent at MPA-5 (Table 3.1). Initial TVH concentrations ranged from 110 ppmv for MPA-5 to 9,600 ppmv for MPB-9.5. Soil samples collected from the VW, MPA, and MPB, had TRPH concentrations of not detected (ND), ND, and 13 milligrams per kilogram (mg/kg), respectively. As discussed in Section 2.1.1, these TRPH values are unexpectedly low and may not represent the actual concentrations.

Oxygen utilization occurred at rapid rates at all MPs, ranging from 0.07 to 0.14 percent per minute (Table 3.4). Based on these oxygen utilization rates, an estimated 15,780 to 31,550 milligrams (mg) of fuel per kilogram (kg) of soil can theoretically be degraded each year at this site. This estimate is based on an average air-filled porosity of approximately 0.11 liter per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded.

3.1.5 Potential Air Emissions

The long-term potential for air emissions from full-scale bioventing operations at this site is low because of the concrete pavement, the relatively low-permeability near-surface silt soil overlying a silty clay, and the low air injection rate. Emissions should be minimal because accumulated vapors will move slowly outward from the air injection VW and will be biodegraded as they move horizontally through the soil.

3.2 POL Storage Area

3.2.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all MPs were purged until oxygen levels had stabilized, and initial oxygen, carbon dioxide, and TVH concentrations were sampled using portable gas analyzers, as described in the technical protocol document (Hinchee et al., 1992). Unusually high ground water and saturated soil conditions prevented the sampling of 5 of the 6 MPs installed. As a result, the VW and MPC-4 were the only points available for soil gas sampling during this period of

Figure 3.1
Respiration Test
MPB-9.5
Building 30
Offutt AFB, NE

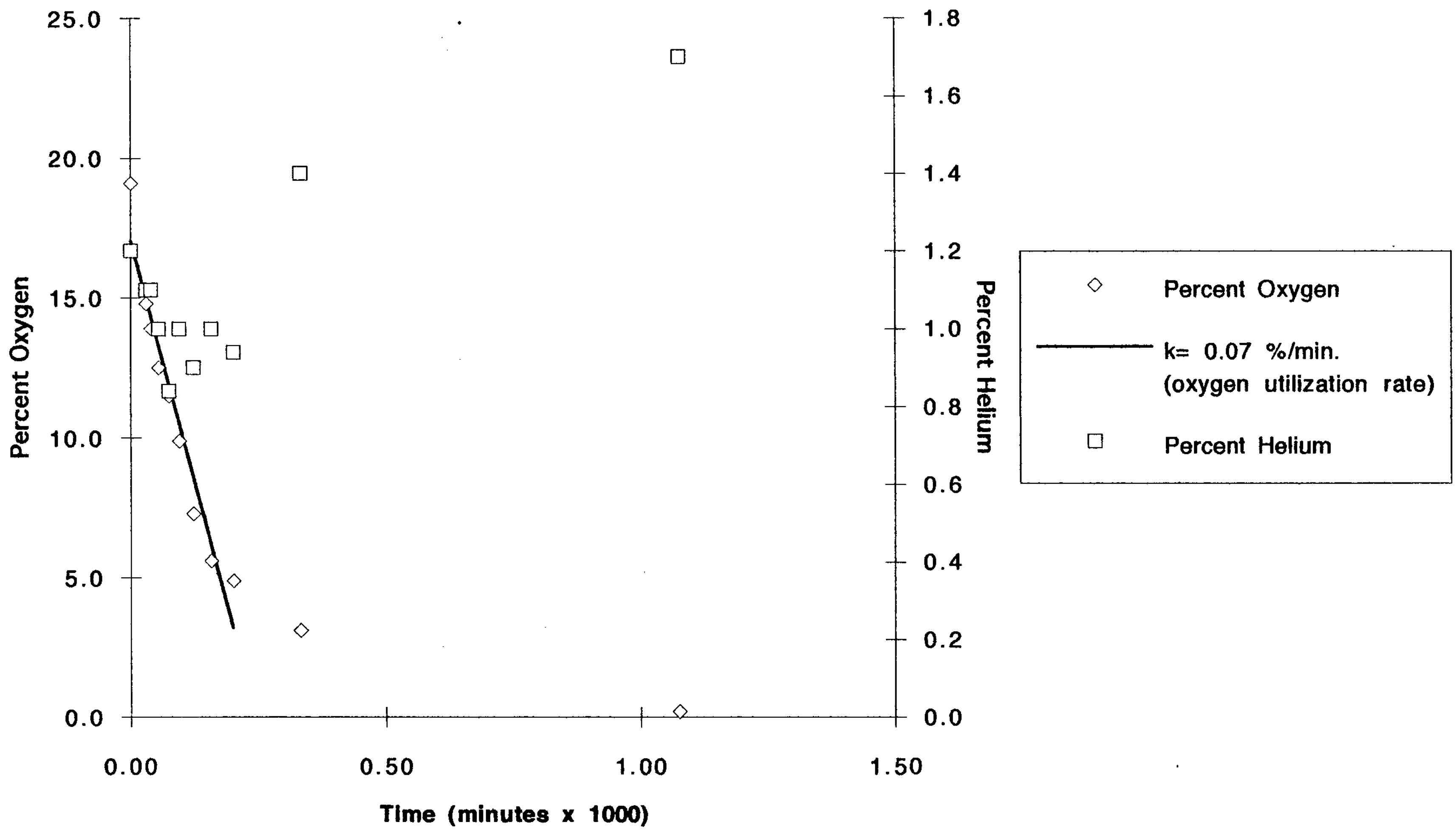


Figure 3.2
Respiration Test
MPC-5
Building 30
Offutt AFB, NE

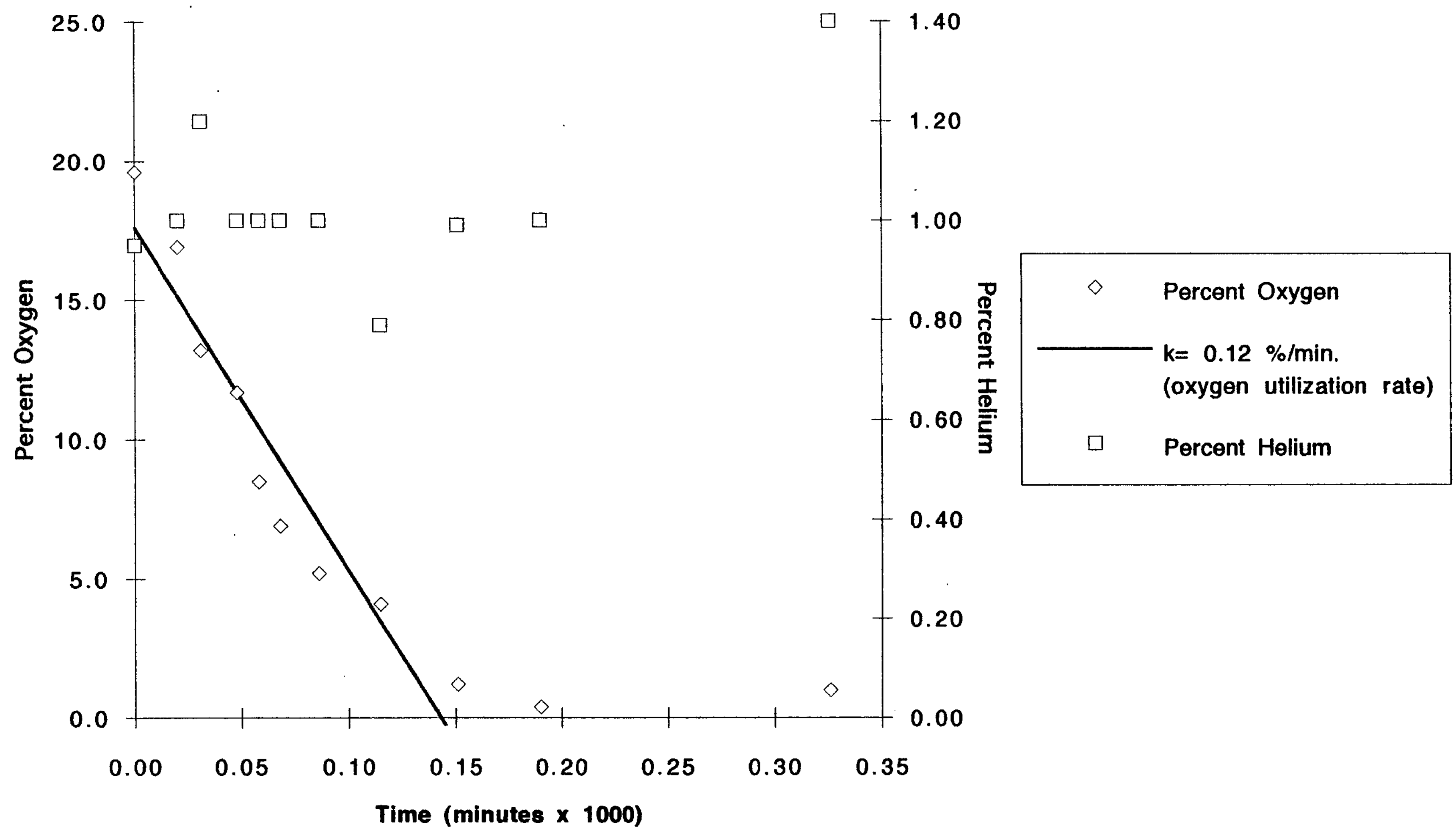


Figure 3.3
Respiration Test
MPC-9.5
Building 30
Offutt AFB, NE

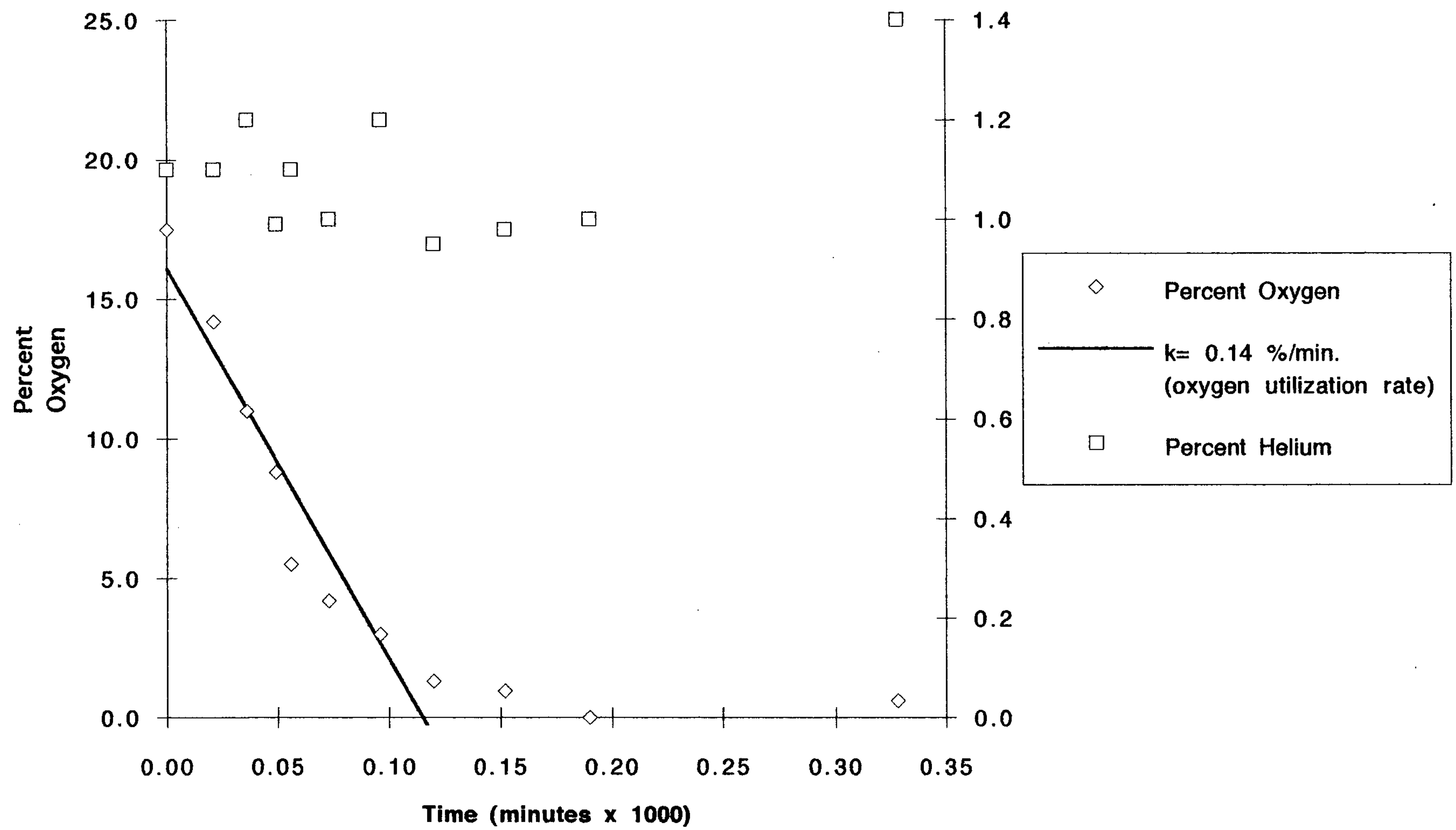


TABLE 3.4
OXYGEN UTILIZATION RATES
BUILDING 30
OFFUTT AFB, NEBRASKA

Location	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
MPB-9.5	19.1	2,837	0.07
MPC-5	19.2	2,822	0.123
MPC-9.5	17.5	2,822	0.14

a/ Actual measured oxygen loss.
b/ Elapsed time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on best-fit lines (Figures 3.1 through 3.3).

testing. These intervals will be sampled for the 6-month respiration test if groundwater levels return to the previous normal for this area of 8 to 11 feet bgs. At the two points sampled, the VW and MPC-4, microorganisms had slightly depleted soil gas oxygen supplies. Initial oxygen concentrations were 13.2 percent for the VW and 12.6 percent for MPC-4. Initial field TVH concentrations in soil gas were >10,000 and 1,200 ppmv, respectively. Soils sampled at the 3- to 5-foot bgs interval appear to have only minor amounts of fuel contamination. It is likely that deeper soils contain greater contamination and would also be depleted of oxygen. Table 3.5 summarizes the initial soil gas chemistry.

3.2.2 Air Permeability

An air permeability test was conducted according to protocol document procedures. Air was injected into the VW for 19 hours at a rate of approximately 10 scfm and an average pressure of 81 inches of water. The injection air pressure was maintained at 81 inches of water throughout the test by adjusting the flow rate. The maximum pressure response at the shallow (4-foot) interval at each MP is listed in Table 3.6. The pressure measured at the MPs gradually increased at a regular rate throughout the period of air injection. A radius of pressure influence of at least 25 feet was observed in the upper four feet of the soil profile. As discussed in the protocol document, the dynamic method of determining soil gas permeability that is coded in the HyperVentilate® model is only appropriate for soils which reach steady state in a time greater than 10 minutes In this pilot test, steady-state conditions were reached approximately 4 hours into the test, and the HyperVentilate® model was used. The resulting calculated permeabilities are listed in Table 3.6. It is important to note that these permeabilities only apply to soils at the 4-foot depth interval and do not represent permeabilities of soils at greater depth.

3.2.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection into the central VW during pilot testing is the primary design parameter for full-scale bioventing systems. Optimization of full-scale and multiple VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Table 3.7 presents the change in soil gas oxygen levels at MPC-4 that occurred during the 19-hour period of injection using the extended pilot test blower unit. Soil gas samples could not be extracted from MPA-4 and MPB-4 due to excessive soil moisture. Based on the oxygen increase at MPC-4, it is anticipated that the radius of oxygen influence for a long-term bioventing system will eventually exceed 25 feet at all depths using a regenerative blower. Monitoring during the extended pilot test at this site will better define the effective treatment radius in the deeper soils as the water table drops.

3.2.4 In Situ Respiration Rates

The *in situ* respiration test was performed by injecting a mixture of air (oxygen) and approximately 2.0 percent helium (inert tracer gas) into the VW and MPC-4 for a 19-hour period. Oxygen loss and other changes in soil gas composition over time

TABLE 3.5
INITIAL SOIL GAS CHEMISTRY
POL STORAGE AREA
OFFUTT AFB, NEBRASKA

Sample Location	Depth (ft)	O_2 (%)	CO_2 (%)	Field TVH (ppmv)[a/]	Lab TVH (ppmv)[b/]	Soil TRPH (mg/kg)[c/]
MPA	4	NS[d/]	NS	NS	NS	ND[e/]
MPB	4	NS	NS	NS	NS	ND
MPC	4	12.6	4.9	1,200	1,000	NS
VW	8-13	13.2	4.8	>10,000	26,000	6.5

a/ Field screening results, in parts per million, volume per volume (ppmv).
b/ Laboratory results.
c/ Laboratory soil results, in milligrams per kilogram (mg/kg).
d/ NS = not sampled.
e/ ND = not detected.

TABLE 3.6

MAXIMUM PRESSURE RESPONSE AND CALCULATED PERMEABILITY
AIR PERMEABILITY TEST
POL STORAGE AREA
OFFUTT AFB, NEBRASKA

Monitoring Point	Distance from VW (feet)	Depth (feet)	Maximum Pressure Response (inches H_2O)	Calculated Air Permeability (Darcys)[a/]
OF3-MPA-4	4.8	4	2.6	0.4
OF3-MPB-4	14.8	4	6.6	1.1
OF3-MPC-4	24.8	4	0.21	71

a/ Calculated using Method 2 of the HyperVentilate® program.

TABLE 3.7
INFLUENCE OF AIR INJECTION AT VENT WELL ON MONITORING POINT OXYGEN LEVELS POL STORAGE AREA OFFUTT AFB, NEBRASKA

MP	Distance From VW (ft)	Depth(ft)	Initial O_2(%)	Final O_2 (%) Long-term System[a/]
A	4.8	4	NA	NA
B	14.8	4	NA	NA
C	24.8	4	12.6	16.2

a/ Reading taken after approximately 19 hours of injection using long-term blower system.

were then measured at the VW and MPC-4. MPA-4 and MPB-4 were not used because of very low soil permeability. Oxygen, TVH, carbon dioxide, and helium were measured for a period of 20 hours following air injection. The measured oxygen loss was then used to calculate the biological oxygen utilization rate. The results of *in situ* respiration testing at selected points at this site are presented in Figures 3.4 and 3.5. Additional results are included in Appendix A. Table 3.8 provides a summary of the oxygen utilization rates.

Because helium is a conservative, inert gas, the change in helium concentrations over time can be useful in determining the effectiveness of the bentonite seals between MP screened intervals. Figures 3.4 and 3.5 compare oxygen utilization and helium retention at the VW and MPC-4, respectively. Because the observed helium loss was negligible, and because helium will diffuse approximately three times faster than oxygen due to oxygen's greater molecular weight, the measured oxygen loss is the result of bacterial respiration and not due to faulty MP construction.

Soil samples collected at 3 to 5 feet bgs from the VW, MPA, and MPB, had TRPH concentrations of 6.5, ND, and ND mg/kg, respectively. Oxygen utilization occurred at relatively slow rates of 0.03 percent per minute at the VW and 0.001 percent per minute at MPC-4. At MPC-4, oxygen concentrations dropped from 20.8 percent to 19.3 percent in 1,180 minutes. Low rates of oxygen utilization in these soils are probably the result of lower levels of contamination at the top of the fuel smear zone.

Based on these oxygen utilization rates, an estimated 320 to 7490 mg of fuel per kg of soil can theoretically be degraded each year at this site. This estimate is based on an average air-filled porosity of approximately 0.12 liter per kg of soil, and a ratio of 3.5 mg of oxygen consumed for every 1 mg of fuel biodegraded. Actual rates may exceed these estimates, particularly in deeper, more contaminated soils.

3.2.5 Potential Air Emissions

The long-term potential for air emissions from full-scale bioventing operations at this site is moderate. This area is grass covered and had several underground pipes which may act as conduits for petroleum vapors. These concerns may be offset by the dense soil matrix and the low air injection rate at this site. Emissions should be minimal because accumulated vapors will move slowly outward from the air injection point and will be biodegraded as they move horizontally through the soil.

4.0 RECOMMENDATIONS

4.1 BUILDING 30

Initial bioventing tests at this site indicate that oxygen has been depleted in the contaminated soils, and that air injection is an effective method of increasing aerobic fuel biodegradation. ES and AFCEE have recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of time, available nutrients, and changing temperatures on fuel biodegradation rates.

TABLE 3.8
OXYGEN UTILIZATION RATES
POL STORAGE AREA
OFFUTT AFB, NEBRASKA

Location	O_2 Loss[a/] (%)	Test[b/] Duration (min)	O_2 Utilization[c/] Rate (%/min)
MPC-4	1.5	1181	0.001
VW	8.2	1152	0.03

a/ Actual measured oxygen loss.
b/ Elapsed time from beginning of test to time when minimum oxygen concentration was measured.
c/ Values based on best-fit lines (Figures 3.4 and 3.5).

Figure 3.4
Respiration Test
OF3-VW
POL Area
Offutt AFB, NE

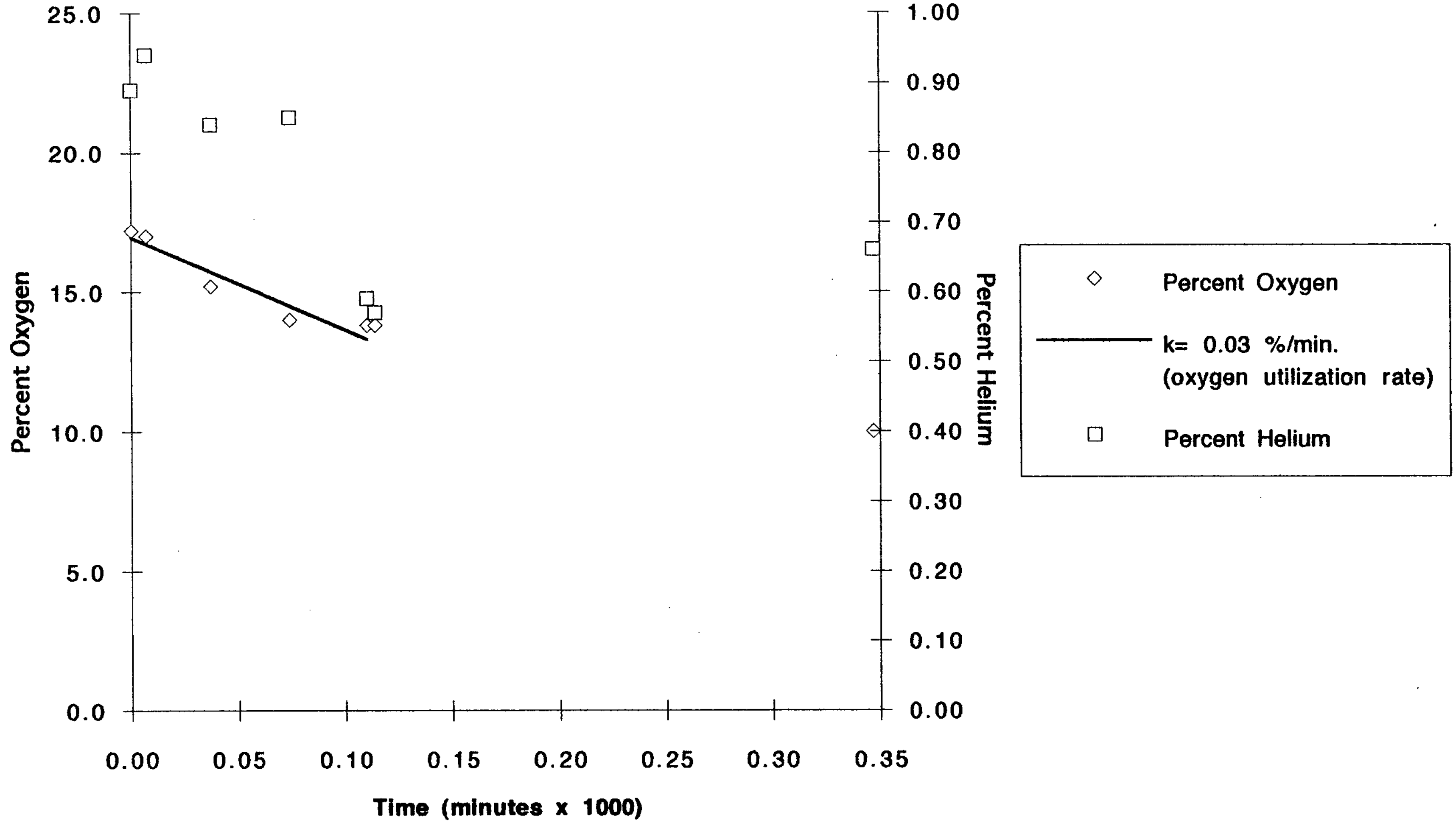
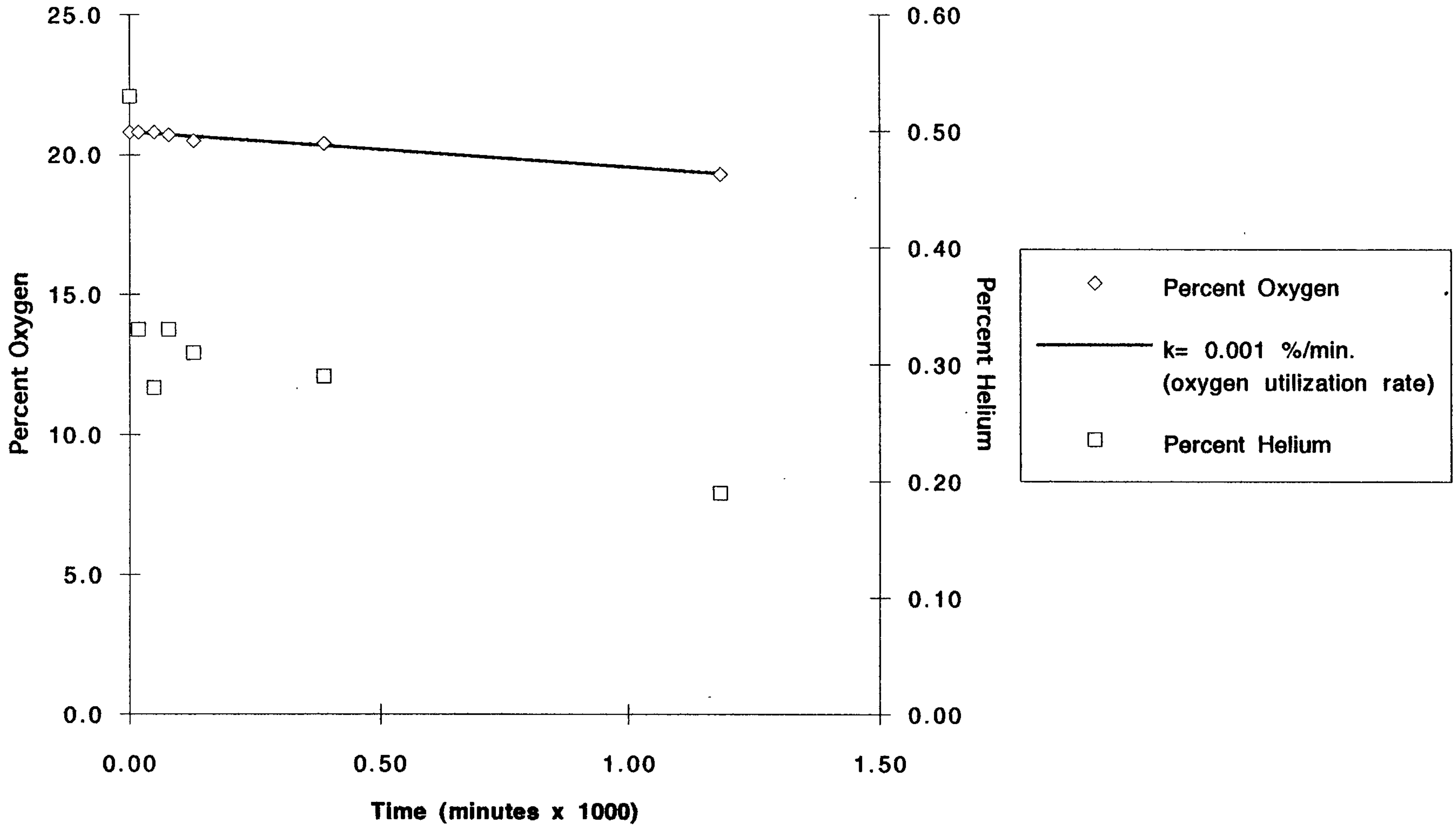


Figure 3.5
Respiration Test
MPC-4
POL Area
Offutt AFB, NE



A small, 1-horsepower regenerative blower has been installed at the site to continue air injection at a rate of approximately 10 scfm. The electrical work was completed and the blower system started the week of May 3, 1993. In November 1993, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test. In May 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the plant in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.
3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

4.2 POL STORAGE AREA

Initial bioventing tests at this site were only partially successful due to the high water table. ES and AFCEE have recommended that air injection continue at this site to determine the long-term radius of oxygen influence and the effect of dropping water table, time, available nutrients, and changing temperatures on fuel biodegradation rates.

A small, 1-horsepower regenerative blower has been installed at the site to continue air injection at a rate of approximately 10 scfm. The electrical work was completed and the blower system was started the week of May 3, 1993. In November 1993, ES will return to the site to sample and analyze the soil gas and conduct a repeat respiration test with special emphasis on the deep MPs which were unavailable for testing due to the high water table. In May 1994, a final respiration test will be conducted, and soil and soil gas samples will be collected from the site to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of three options:

1. Upgrade, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the plant in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling indicates significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved.

3. If significant difficulties or poor results are encountered during bioventing at this site, AFCEE may recommend removal of the blower system and proper abandonment of the VW and MPs.

5.0 REFERENCES

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for USAF Center for Environmental Excellence. May.

APPENDIX A
GEOLOGIC BORING LOGS, CHAIN-OF-CUSTODY FORMS, TEST DATA, AND CALCULATIONS

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	CLIENT:	AFCEE	DATE:	27-APRIL-93
BORING NO.:	OF2-VW	BORING DIA.:	12.0-INCH	ELEV:	1024
RIG TYPE:	ACKER	CONTRACTOR:	LAYNE-WESTERN	DATM:	GROUND SURFACE
TEMP (°F):	65	WEATHER:	CLOUDY, RAINY	GEOL:	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
			0.5 ft. concrete					HCA SOIL: 0.0/30.0
1			Dk. Brn CLAY with silt, moist, fill					HCA BZ: 0.0/0.0
2								
3								
4								
5		CL	Lt. Brn. CLAY w/ sm silt, moist, plastic					HCA SOIL: 0.0/8.0
								HCA BZ: 0.0/0.0
6								
7								
8								
9			Green-Brn. CLAY w/ sm silt, moist					Discoloration
10			Green CLAY, sm silt, tr. pebbles, hydrocarbon odor					HCA CUTTINGS: 0.0/5.0
				OF2-	10-12			HCA SOIL SAMPLE: 0.0/42.0
11				VW-10		S	4,3,6	
12								
13								TD @ 13.0'
14								
15								
16								
17								
18								
19								
20								

BH - Bore Hole
SAA - Same As Above
sm - some
& - and
@ - at
tr - trace

water table
brn - brown
w/ - with
Lt - light
HCA - hydrocarbon ar

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

ENGINEERING-SCIENCE, INC.

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	CLIENT:	AFCEE	DATE:	27-APRIL-93
BORING NO.:	OF2-MPA	BORING DIA.:	8.5-INCH	ELEV:	1024
RIG TYPE:	ACKER	CONTRACTOR:	LAYNE-WESTERN	DATM:	GROUND SURFACE
TEMP (°F):	70	WEATHER:	CLOUDY, RAINY	GEOL:	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
			0.5 ft. concrete					HCA soil: 0.0/24.0
1			Dk. Brn. SILT w/ clay fill, moist to 1.0'					HCA bz: 0.0/0.0
		CL	Brn. CLAY sm silt, moist tr pebbles					
2								
3								
4								
5								
6			SAA					HCA soil: 0.0/21.0
7								
8				OF2-MPA-8	8-10		5,6,7	
9						S		
10								TD @ 10.0'
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH – Bore Hole
SAA – Same As Above
sm – some
& – and
@ – at
tr – trace

warer table
brn – brown
w/ – with
Lt – light
HCA – hydrocarbon ar

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	CLIENT:	AFCEE	DATE:	28-APRIL-93
BORING NO.:	OF2-MPB	BORING DIA.:	8.5-INCH	ELEV:	1024
RIG TYPE:	ACKER	CONTRACTOR:	LAYNE-WESTERN	DATM:	GROUND SURFACE
TEMP (°F):	70	WEATHER:	WINDY, COOL	GEOL:	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
			0.5 ft. concrete					HCA soil: 0.0/40.0
1			Dk. Brn. SILT w/ clay, fill, moist					HCA bz: 0.0/0.0
2								
3								
4								
5		CL	Green CLAY w/silt, moist v. sl. odor, tr. pebbles					
6								
7								
8			Green CLAY w/silt, sm pebbles, moist, tr. shells	OF2-	8-10		3,3,7	HCA soil: 0.0/40.0
				MPB-8				HCA bz: 0.0/0.0
9						S		
10								TD @ 10.0'
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH – Bore Hole
SAA – Same As Above
sm – some
& – and
@ – at
tr – trace

water table
brn – brown
w/ – with
Lt – light
HCA – hydrocarbon ar

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	**CLIENT:**	AFCEE	**DATE:**	28–APRIL–93
BORING NO.:	OF2–MPC	**BORING DIA.:**	8.5–INCH	**ELEV:**	1024
RIG TYPE:	ACKER	**CONTRACTOR:**	LAYNE–WESTERN	**DATM:**	GROUND SURFACE
TEMP (°F):	70	**WEATHER:**	WINDY, SUNNY, COOL	**GEOL:**	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro–file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
			0.5 ft. concrete					
1		CL	Med. Brn. CLAY w/ silt fill, moist, tr. glass, brick,					
			pebbles					
2								
3								
4								
5								
								HCA bz: 0.0/2.0
6			Med. Green CLAY w/ silt, tr pebbles, moist					HCA borehole: 0.0/60.0
7								
8				OF2–	8–10			
				MPC–8				
9						S		
10			SAA					TD @ 10.0'
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH – Bore Hole
SAA – Same As Above
sm – some
& – and
@ – at
tr – trace

water table
brn – brown
w/ – with
Lt – light
HCA – hydrocarbon analyzer

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	CLIENT:	AFCEE	DATE:	29-APRIL-93
BORING NO.:	OF3-VW	BORING DIA.:	12.0-INCH	ELEV:	965
RIG TYPE:	ACKER	CONTRACTOR:	LAYNE-WESTERN	DATM:	GROUND SURFACE
TEMP (°F):	70	WEATHER:	SUNNY	GEOL:	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
		ML	0.5 ft. Fill, Med. Brn. SILT, tr. pebbles, sl moist, odor					
1			asphalt debris					
2								HCA borehole: 0.0/10.0
3				OF3-VW-3	3-5	S	8,13,17	
4								
		SM	Dk. Grey SAND, sm silt, sl., moist, hydrocarbon odor					
5								
6								
7								
8								
9								TD @ 9.0'
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH – Bore Hole
SAA – Same As Above
sm – some
& – and
@ – at
tr – trace

water table
brn – brown
w/ – with
Lt – light
HCA – hydrocarbon analyzer

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	**CLIENT:**	AFCEE	**DATE:**	29-APRIL-93
BORING NO.:	OF3-MPA	**BORING DIA.:**	8.5-INCH	**ELEV:**	965
RIG TYPE:	ACKER	**CONTRACTOR:**	LAYNE-WESTERN	**DATM:**	GROUND SURFACE
TEMP (°F):	70	**WEATHER:**	SUNNY	**GEOL:**	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
		ML	Med. Brn SILT w/ sand, tr pebbles - Fill to 4.5 ft					
1								
2								
3				OF3-MPA-3	3-5			
4						S	9,22,17	
		SM	Med. grey SAND, tr silt, moist, hydrocarbon odor and discoloration					
5								
6								
7			SAA					
8								
9								TD @ 7.5'
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH - Bore Hole
SAA - Same As Above
sm - some
& - and
@ - at
tr - trace

water table
brn - brown
w/ - with
Lt - light
HCA - hydrocarbon analyzer

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	CLIENT:	AFCEE	DATE:	29–APRIL–93
BORING NO.:	OF3–MPB	BORING DIA.:	8.5–INCH	ELEV:	965
RIG TYPE:	ACKER	CONTRACTOR:	LAYNE–WESTERN	DATM:	GROUND SURFACE
TEMP (°F):	70	WEATHER:	SUNNY	GEOL:	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro–file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
		ML	Med. Brn SILT w/ sand, tr pebbles – Fill to 5.0 ft					
1								
2								
3				OF3–	3–5			HCA BZ: 0 0/1.0
				MPB–3				HCA SOIL: 0.0/8.0
4						S	9,19,12	
5		SM	Med. grey SAND, tr silt, moist, hydrocarbon odor and					
			discoloration					
6								
7			SAA					
8								
9								TD @ 7.5'
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH – Bore Hole
SAA – Same As Above
sm – some
& – and
@ – at
tr – trace

water table
brn – brown
w/ – with
Lt – light
HCA – hydrocarbon ar

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

GEOLOGIC BORING LOG

JOB NO.:	DE268.10.04	**CLIENT:**	AFCEE	**DATE:**	29-APRIL-93
BORING NO.:	OF3-MPC	**BORING DIA.:**	8.5-INCH	**ELEV:***	<1048
RIG TYPE:	ACKER	**CONTRACTOR:**	LAYNE-WESTERN	**DATM:**	GROUND SURFACE
TEMP (°F):	70	**WEATHER:**	SUNNY, SL BREEZE	**GEOL:**	JEW
		DRLG MED:	NONE		

Depth (ft.)	Pro-file	USCS	Geologic Description	Samples No.	Samples Depth (ft)	Sample Type	Blow Counts	Remarks HCA = (hexane units)
		ML	Med. Brn SILT w/ sand, tr pebbles, sl moist - Fill to 5.0 '					
1								
2								
3				OF3-MPC-3	3-5			HCA borehole: 0.0/22.0
4						S	6,10,17	
5		SM	Med. grey SAND, tr silt, moist, hydrocarbon odor and discoloration					
6								
7								
8			Med. grey SAND, saturated					TD @ 8.0'
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

BH - Bore Hole
SAA - Same As Above
sm - some
& - and
@ - at
tr - trace

water table
brn - brown
w/ - with
Lt - light
HCA - hydrocarbon ar

S SPLIT SPOON SAMPLE
GRAB SAMPLE
EST. WATER TABLE

Figure [illegible]

CHAIN OF CUSTODY RECORD

Page ____ of ____

ENGINEERING-SCIENCE, INC. 1700 BROADWAY, SUITE 900 DENVER, COLORADO 80290 303-831-8100	AFCEE BIOVENTING PILOT TESTS	Ship To:
ES Job No. DE268.10.04	Base: OFFUTT Site: BLDG. 30 + POL STORAGE AREA	ENGINEERING-SCIENCE LABORATORY ~~600 Bancroft Way~~ ~~Berkeley, CA 94710~~ STACY HOCH Attn: ~~Tom Paulson~~ ~~(510) 841-7353~~
Sampler(s): (Signature) James E. Wallin, David Teets		

Preservative: NONE (SW 9045, A 403, SW 7380, SW 846); HOLD AT 4C (SW 8020, E 418.1); NONE (E 351.2, E 365.3, UCM)

Analysis Required

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	SW 9045 (PH)	A 403 (ALKA)	SW 7380 (IRON)	SW 846 (MOIST)	SW 8020 (BTEX)	E 418.1 (TRPH)	E 351.2 (TKN)	E 365.3 (PHOS)	UCM (CLASS)	Sample Type	Matrix	Remarks
4/27/93	1500	OF2-VW-10	6267.1	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	G C	SOIL	
4/29/93	1645	OF2-MPA-8	9.8	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	G C	SOIL	[illegible] 4/27/93
4/23/93	1245	OF2-MPB	10.1	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	G C	SOIL	
4/29/93	1200	OF3-VW-3	11.0	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	G C	SOIL	
4/29/93	1430	OF3-MPA-3	12.8	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	G C	SOIL	
4/29/93	1400	OF3-MPB-3	13.6	4	✓	✓	✓	✓	✓	✓	✓	✓	✓	G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	
														G C	SOIL	

Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time	Remarks:
J. Wallin to FEDEX	4/30/93 1610	Via FedEx		
Relinquished by: (Signature)	Date / Time	Recieved for Laboratory by: (Signature)	Date / Time	G - Grab Sample, C - Composite Sample
		[illegible]	5/1 [illegible]	

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files

Federal Express Number: 1207623060

Airbill Number: ____

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 • Denver, Colorado
(303) 831-8100

CCRSOIL

Figure C.3

CHAIN OF CUSTODY RECORD

Page ___ of ___

ENGINEERING-SCIENCE, INC.
1700 BROADWAY, SUITE 900
DENVER, COLORADO 80290
303-831-8100

ES Job No. DE268. 10.04

AFCEE BIOVENTING PILOT TESTS

Base: OFFUTT AFB

Site: BLDG 30 + (OF2)
POL → (OF3)

Sampler(s): (Signature) James E. Walters, David Tufts

Preservative: NONE

Ship To:

AIR TOXICS LTD.
11325 Sunrise Gold Circle, Suite 4
Rancho Cordova, CA 95742

Attn: Bob Freeman
(916) 638-9892

Date	Time	Sample Description	Lab I.D.	No. of Contrs.	TO-3(EPA)	(BTEX & TPH)	Sample Type	Matrix	Remarks
5/1/93	1445	OF2 - VW ~~A~~ 1		1	X	X	G C	AIR	
5/1/93	1500	OF2 - MP C - 9.5		1	X	X	G C	AIR	
5/1/93	1515	OF2 - MP B - 9.5		1	X	X	G C	AIR	
5/1/93	1800	OF3 - VW		1	X	X	G C	AIR	
5/1/93	1720	OF3 - MPC - 4		1	X	X	G C	AIR	
~~5/1/93~~		~~OF3~~					G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	
							G C	AIR	

Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks:
James E. Walters to FED EX	5-5-93			
Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	G - Grab Sample, C - Composite Sample

Distribution: Original Accompanies Shipment. Copies to: Coordinator Field Files 6MA55

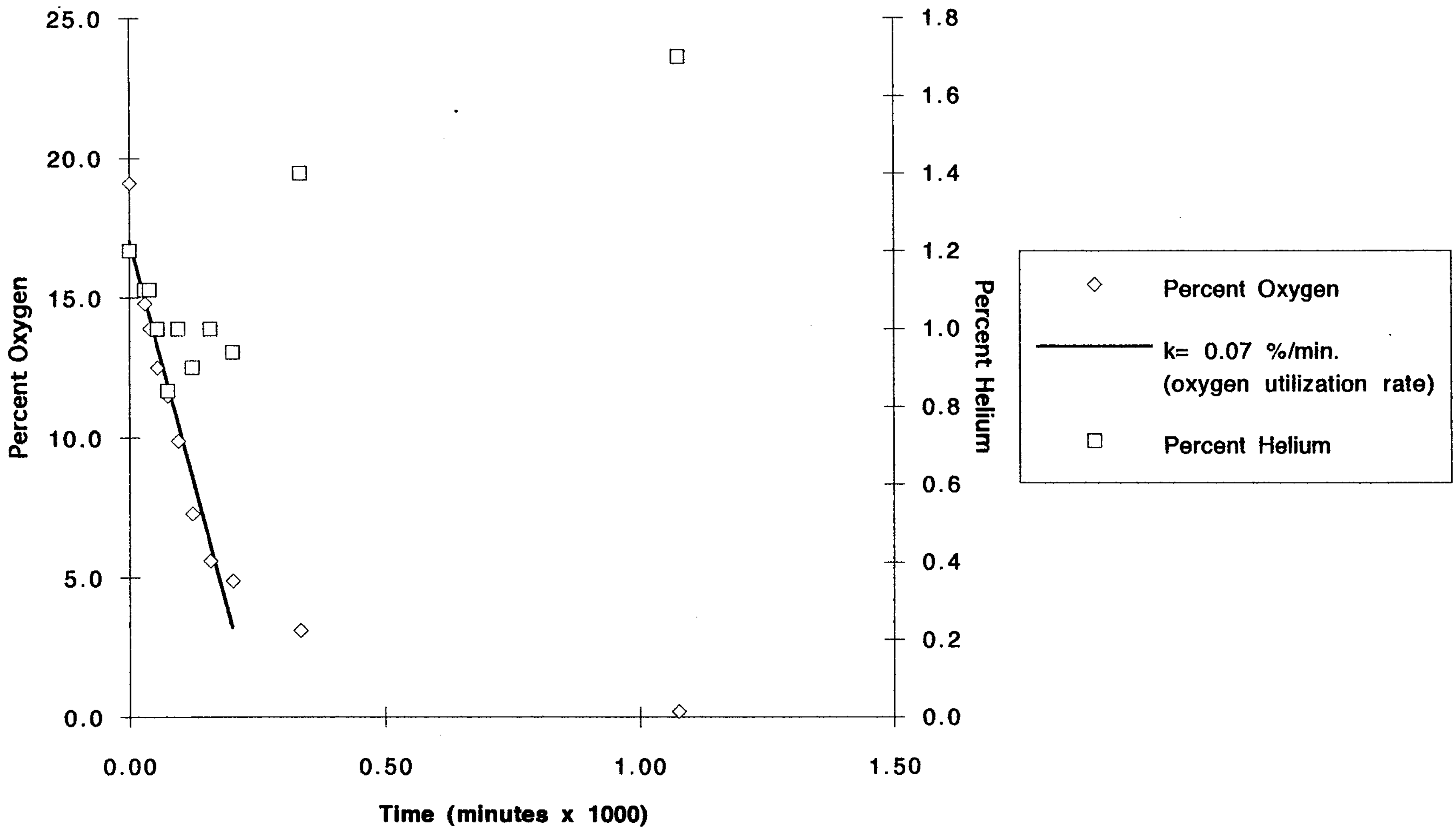
Federal Express Number: 1873400314

Airbill Number: ___

ENGINEERING-SCIENCE, INC.
1700 Broadway, Suite 900 · Denver, Colorado
(303) 831-8100

CCRAIR

Respiration Test
MPB-9.5
Building 30
Offutt AFB, NE



OFFUTT AFB – BUILDING 30
Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: OF2–MPB–9.5 K_o = max. observed rate 0.070 %/min.

w = moisture content 23 %

Assume: Soil properties for windblown silt Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	n =	0.50
Unit weight (dry):	^{g}d =	1.36
Void ratio:	$e = n/1-n$ =	0.99
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.

Solving for 1 liter of soil

a) $V_v = n * 1$ L

V_v = 0.5 liters V_v = void volume

b) $S_r = Gw/e$

S_r = 0.62 S_r = degree of saturation

c) $V_w = S_r \times V_v$

V_w = 0.31 liters V_w = volume of water

d) $V_a = V_v - V_w$

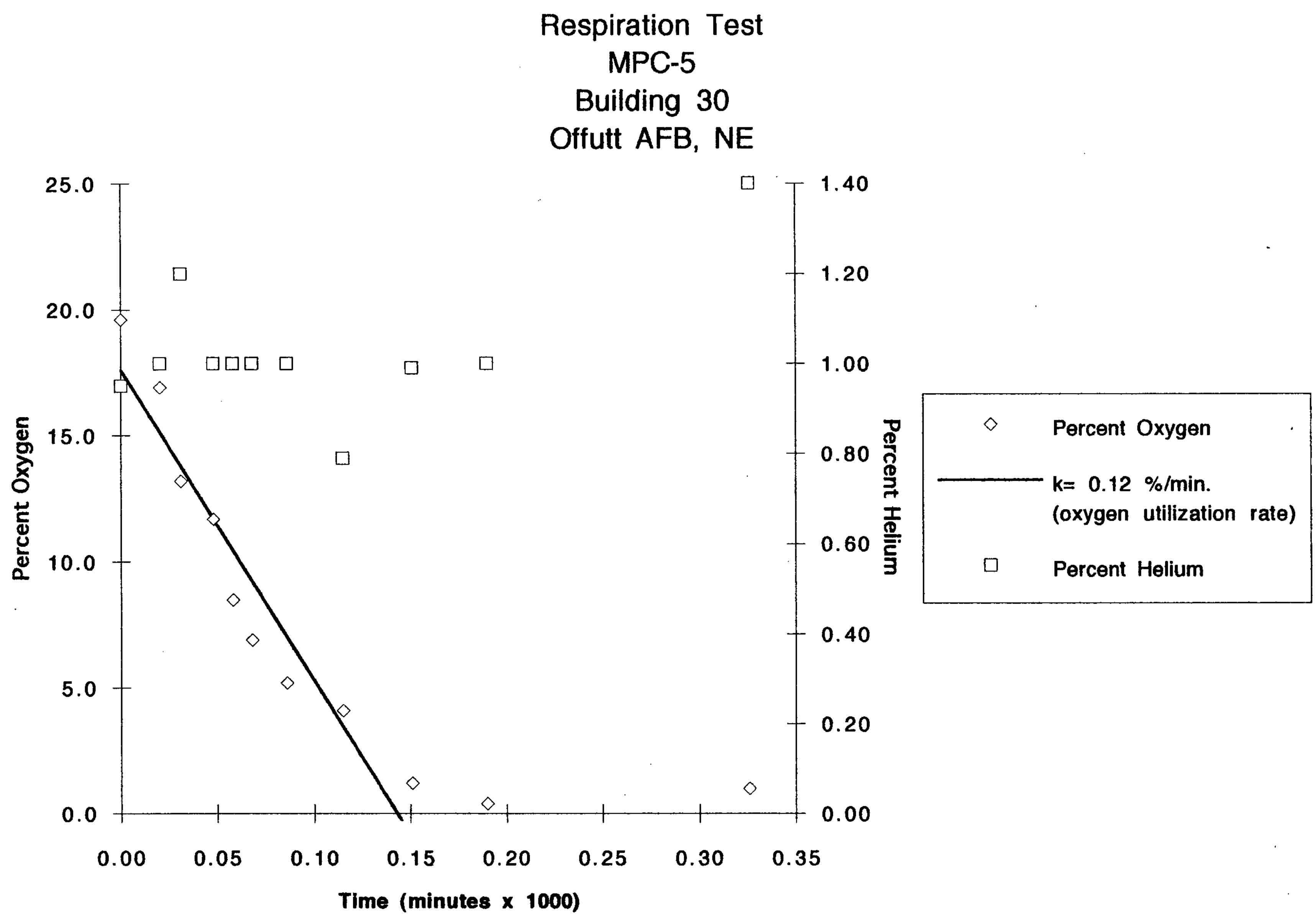
V_a = 0.19 liters V_a = volume of air

e) Bulk density = $^{g}d + (V_w \times {}^{g}w)$ = 1.7 kg/l soil

f) A = V_a/Bulk density = 0.112 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 15780 mg TPH/year

afbio1/offuttd4.wk1/7–22–93


Respiration Test
MPC-5
Building 30
Offutt AFB, NE
Percent Oxygen
Percent Helium
Time (minutes x 1000)
25.0
20.0
15.0
10.0
5.0
0.0
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Percent Oxygen
k= 0.12 %/min.
(oxygen utilization rate)
Percent Helium

OFFUTT AFB – BUILDING 30
Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: OF2–MPC–5 K_o = max. observed rate 0.12 %/min.
w = moisture content 23 %

Assume: Soil properties for windblown silt Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	$n =$	0.50
Unit weight (dry):	$^{g}d =$	1.36
Void ratio:	$e = n/1-n =$	0.99
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.
Solving for 1 liter of soil

a) $V_v = n * 1$ L
V_v = 0.5 liters V_v = void volume

b) $S_r = Gw/e$
S_r = 0.62 S_r = degree of saturation

c) $V_w = S_r \times V_v$
V_w = 0.31 liters V_w = volume of water

d) $V_a = V_v - V_w$
V_a = 0.19 liters V_a = volume of air

e) Bulk density = $^{g}d + (V_w \times {}^{g}w)$ = 1.7 kg/l soil

f) A = V_a/Bulk density = 0.112 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 27050 mg TPH/year

afbio1/offuttd5.wk1/7–22–93

Offutt AFB – Building 30
Steady–state Equation – Air Injection

Enter data

Calculated data

$$k = \frac{Q \mu \ln (Rw / Ri)}{H \pi Patm [1 - (Pw / Patm)^2]}$$

Where:

Q = Volumetric flow rate of vent well

10	scfm x (30.48 cm/ft)^3 x (1 min/60 s) =	4.72E+03	cm^3/s

μ = Viscosity of Air @ 18° C = 1.80E–04 g/cm s

Patm = Ambient pressure @ 1000 feet of elevation

393	inches H2O x (3.61E–2 psia/in. H2O) =	14.187	psia
14.187	psia x (6.89476E4 g/cm s^2)/psia =	9.78E+05	g/cm s^2

Rw = Radius of Vent Well

2	inches x 2.54 cm/in =	5.08	cm

H = Depth of Screen (length of screened interval)

5	feet x 30.48 cm/ft =	152	cm

Ri = Maximum Radius of Venting Influence

25	feet x 30.48 cm/ft =	762	cm

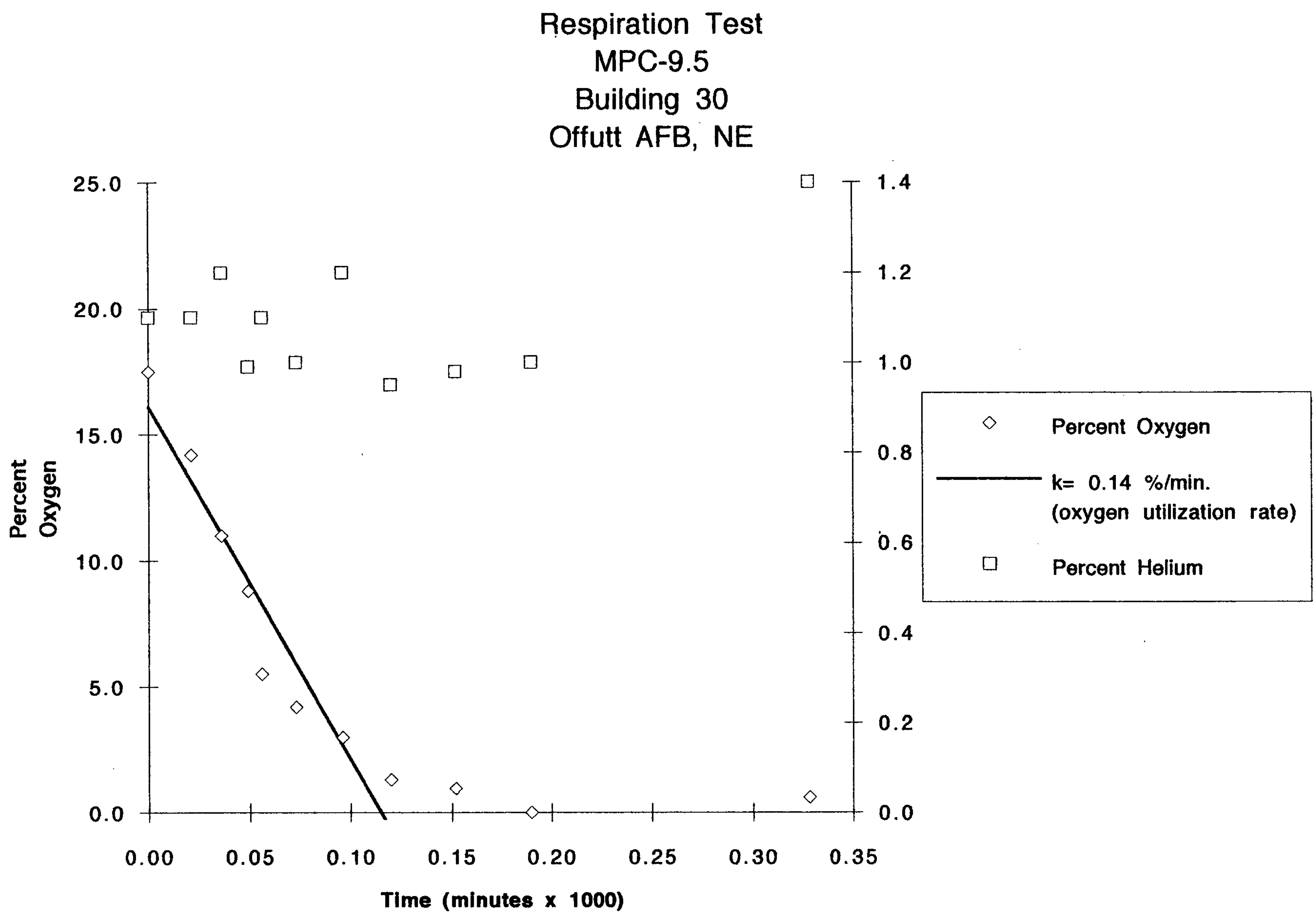
Pw = Absolute Pressure at Vent Well

27	inches H2O x (3.61E–2 psia/in. H2O) =	0.975	psia
0.975	psia + 14.187 psia =	15.162	psia
15.162	psia x (6.89476E4 g/cm s^2)/psia =	1.05E+06	g/cm s^2

k = 6.394E–08 cm^2

6.390E–08	cm^2 x (1 m/100 cm)^2 =	6.400E–12	m^2
6.400E–12	m^2 x 1 darcy/(9.870E–13 m^2) =	6.48	darcys

afbio1/Off2ss1.wk1/7–27–93


Respiration Test
MPC-9.5
Building 30
Offutt AFB, NE
25.0
20.0
15.0
10.0
5.0
0.0
Percent Oxygen
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Time (minutes x 1000)
Percent Oxygen
k= 0.14 %/min.
(oxygen utilization rate)
Percent Helium

OFFUTT AFB – BUILDING 30
Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: OF2–MPC–9.5

K_o =	max. observed rate	0.14	%/min.
w =	moisture content	23	%

Assume: Soil properties for windblown silt Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	n =	0.50
Unit weight (dry):	^{g}d =	1.36
Void ratio:	$e = n/1-n$ =	0.99
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.

Solving for 1 liter of soil

a) $V_v = n * 1$ L

V_v = 0.5 liters V_v = void volume

b) $S_r = Gw/e$

S_r = 0.62 S_r = degree of saturation

c) $V_w = S_r \times V_v$

V_w = 0.31 liters V_w = volume of water

d) $V_a = V_v - V_w$

V_a = 0.19 liters V_a = volume of air

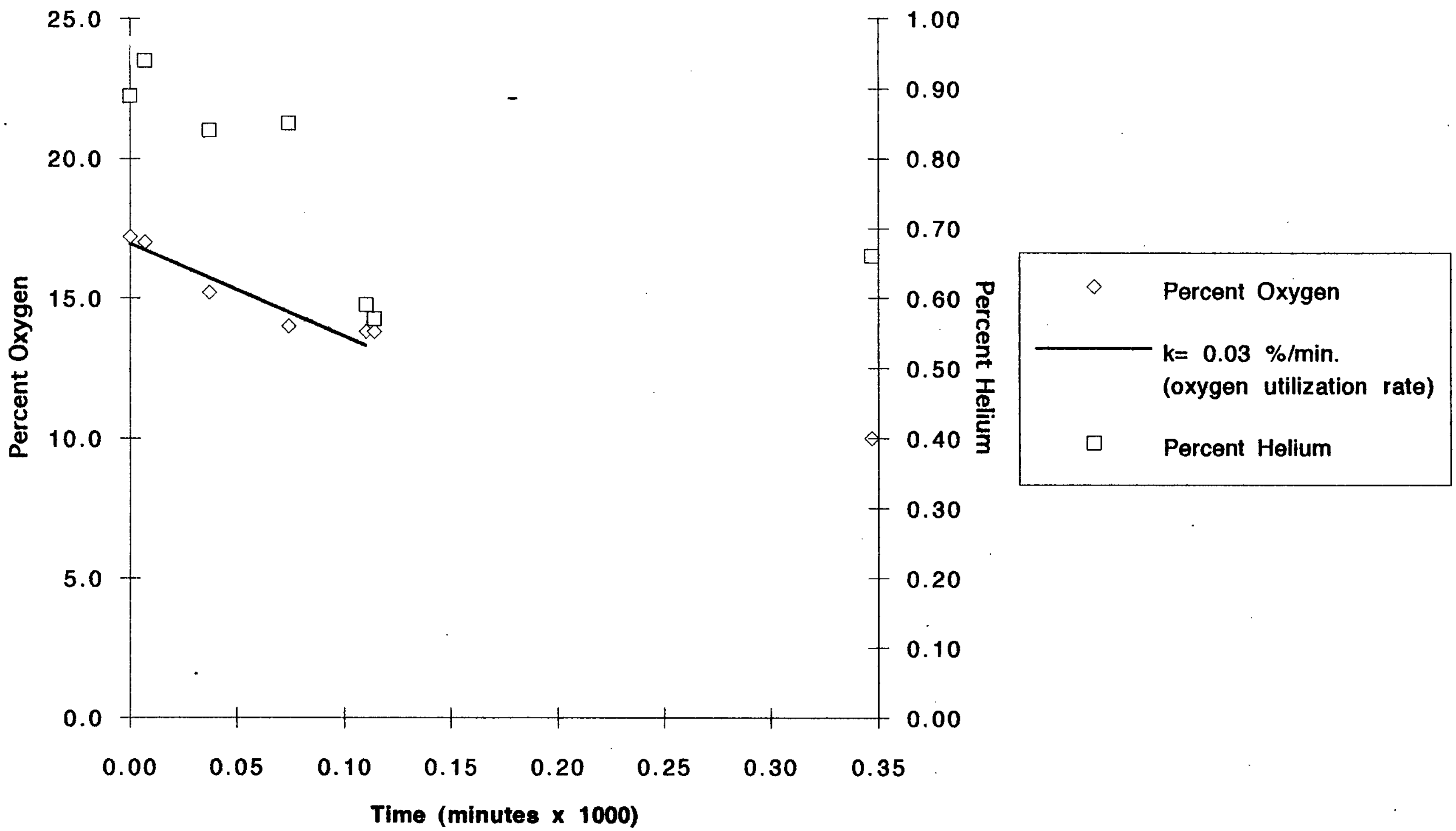
e) Bulk density = $^{g}d + (V_w \times {}^{g}w)$ = 1.7 kg/l soil

f) A = V_a/Bulk density = 0.112 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 31550 mg TPH/year

afbio1/offuttd6.wk1/7–22–93

Respiration Test
OF3-VW
POL Area
Offutt AFB, NE



OFFUTT AFB – POL STORAGE AREA
Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: OF3–VW K_o = max. observed rate 0.03 %/min.
w = moisture content 20 %

Assume: Soil properties for mixed–grain sand Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	n =	0.46
Unit weight (dry):	$^g d$ =	1.43
Void ratio:	$e = n/1-n$ =	0.99
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.
Solving for 1 liter of soil

a) $V_v = n * 1$ L
V_v = 0.46 liters V_v = void volume

b) $S_r = Gw/e$
S_r = 0.54 S_r = degree of saturation

c) $V_w = S_r \times V_v$
V_w = 0.25 liters V_w = volume of water

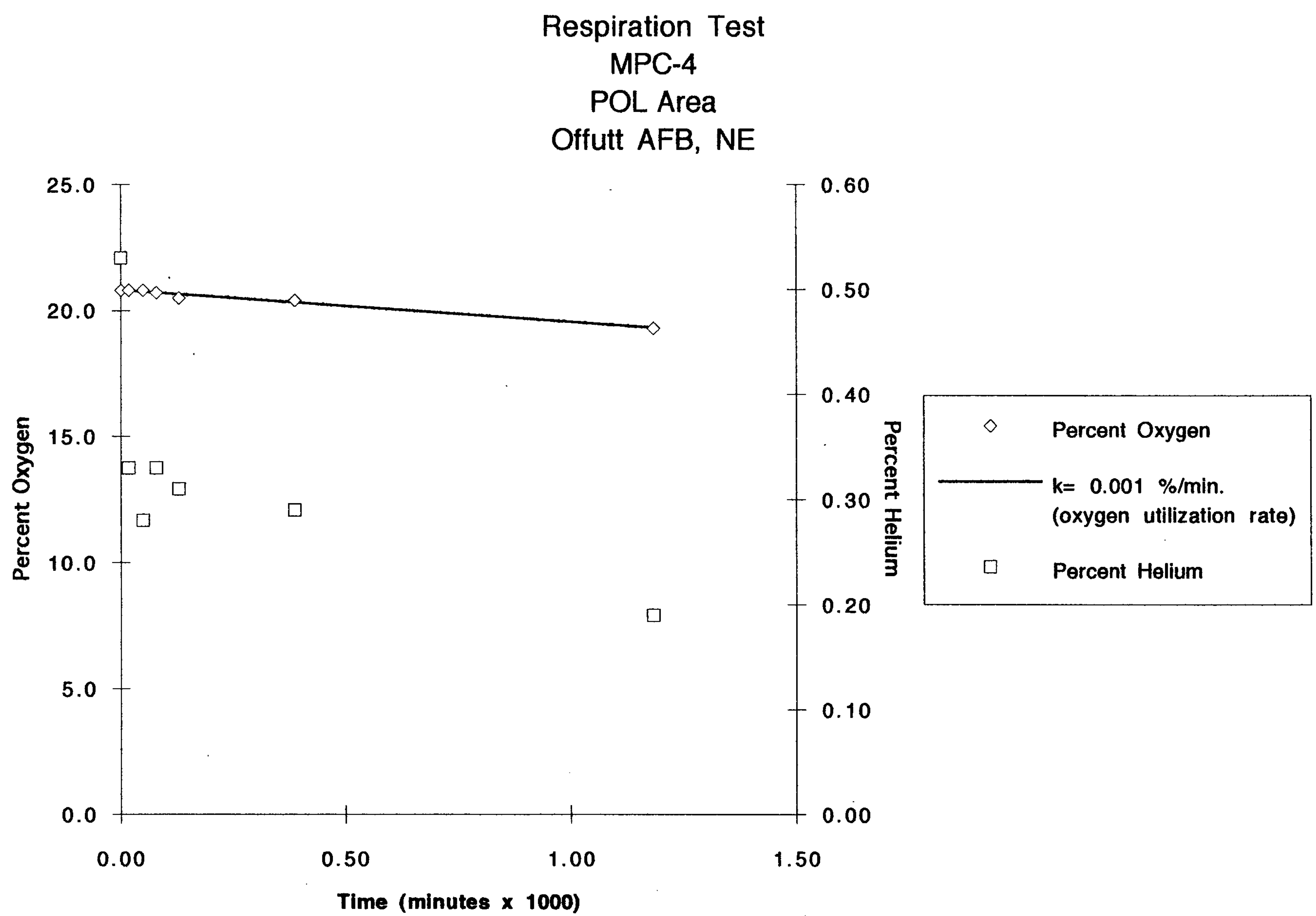
d) $V_a = V_v - V_w$
V_a = 0.21 liters V_a = volume of air

e) Bulk density = $^g d + (V_w \times {}^g w)$ = 1.7 kg/l soil

f) A = V_a/Bulk density = 0.124 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 7490 mg TPH/year

afbio1/offuttd7.wk1/7–22–93


Respiration Test
MPC-4
POL Area
Offutt AFB, NE
Percent Oxygen
25.0
20.0
15.0
10.0
5.0
0.0
Percent Helium
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0.00
0.50
1.00
1.50
Time (minutes x 1000)
Percent Oxygen
k= 0.001 %/min.
(oxygen utilization rate)
Percent Helium

OFFUTT AFB – POL STORAGE AREA
Biodegradation Rate Calculations

enter data	calculated data

Formula: $K_b = K_o \times 1/100\% \times A \times D_o \times C$ Where:

K_b = fuel biodegradation rate

K_o = O_2 utilization rate (%/min.)

A = volume of air/kg soil

D_o = O_2 density 1340 mg/L

C = Carbon/O_2 ratio for hexane mineralization = 1/3.5

Test Results: OF3–MPC–4 K_o = max. observed rate 0.0013 %/min.
w = moisture content 20 %

Assume: Soil properties for mixed–grain sand Specify from Table 1.4 (Ref. Foundation Engineering, Peck, Hanson, and Thornburn, John Wiley Press, 1974)

Porosity:	n =	0.46
Unit weight (dry):	^{g}d =	1.43
Void ratio:	$e = n/1-n$ =	0.99
Specific gravity:	G =	2.65

Calculate A = Air filled volume (V_a)/unit wt.
Solving for 1 liter of soil

a) $V_v = n * 1$ L
V_v = 0.46 liters V_v = void volume

b) $S_r = Gw/e$
S_r = 0.54 S_r = degree of saturation

c) $V_w = S_r \times V_v$
V_w = 0.25 liters V_w = volume of water

d) $V_a = V_v - V_w$
V_a = 0.21 liters V_a = volume of air

e) Bulk density = $^{g}d + (V_w \times {}^{g}w)$ = 1.7 kg/l soil

f) A = V_a/Bulk density = 0.124 l air/kg soil

$K_b = K_o \times 1/100\% \times A \times D_o \times C \times$ 525,600 min/yr = 320 mg TPH/year

afbio1/offuttd8.wk1/7–22–93

Respiration Test
Building 30
Offutt AFB, NE

Monitoring Point	Date	Days Elapsed (frac. days)	Time	Hrs elapsed (fractional days)	Days Elapsed	Elapsed Time (min. x 1000)	O2%	CO2%	Total Hydro-carbon	Helium	Comments			
												Trend of O2/	New	k
OF2-VW	05/04/93	0.00	15:10	0.00	0.00	0.00	16.5	0.7	97	0.96		Time - VW	x-values	0.0009
OF2-VW	05/04/93	0.00	15:36	0.02	0.02	0.03	14.0	0.6	165	1.0		14.0913012	0	
OF2-VW	05/04/93	0.00	15:55	0.03	0.03	0.05	14.1	0.7	210	1.0		10.4278794	4.07	
OF2-VW	05/04/93	0.00	16:07	0.04	0.04	0.06	13.9	0.7	250	0.98				
OF2-VW	05/04/93	0.00	16:45	0.07	0.07	0.10	13.9	0.7	300	0.86				
OF2-VW	05/04/93	0.00	17:58	0.12	0.12	0.17	13.4	0.8	320	0.88				
OF2-VW	05/04/93	0.00	20:19	0.21	0.21	0.31	13.5	0.95	340	1.1				
OF2-VW	05/05/93	1.00	08:40	-0.27	0.73	1.05	12.0	1.1	460	1.3				
OF2-VW	05/06/93	2.00	13:45	-0.06	1.94	2.80	10.0	1.5	680	1.2				
OF2-VW	05/07/93	3.00	10:50	-0.18	2.82	4.06	11.2	1.2	430	0.85				
OF2-VW	05/07/93	3.00	10:55	-0.18	2.82	4.07	11.1	1.2	420	0.81	Resample			
MPB-9.5	05/04/93	0.00	14:50	0.00	0.00	0.00	19.1	0.6	110	1.2		Trend of O2/	New	k
MPB-9.5	05/04/93	0.00	15:20	0.02	0.02	0.03	14.8	0.6	240	1.1		Time-MPB9.5	x-values	0.06914
MPB-9.5	05/04/93	0.00	15:30	0.03	0.03	0.04	13.9	0.8	280	1.1		17.032402	0	
MPB-9.5	05/04/93	0.00	15:45	0.04	0.04	0.06	12.5	0.7	320	1.0		3.20422258	0.2	
MPB-9.5	05/04/93	0.00	16:05	0.05	0.05	0.07	11.5	0.8	310	0.84				
MPB-9.5	05/04/93	0.00	16:25	0.07	0.07	0.10	9.9	0.8	425	1.0				
MPB-9.5	05/04/93	0.00	16:53	0.09	0.09	0.12	7.3	0.8	480	0.90				
MPB-9.5	05/04/93	0.00	17:28	0.11	0.11	0.16	5.6	0.85	585	1.0				
MPB-9.5	05/04/93	0.00	18:12	0.14	0.14	0.20	4.9	0.8	600	0.94				
MPB-9.5	05/04/93	0.00	20:24	0.23	0.23	0.33	3.1	1.0	865	1.4				
MPB-9.5	05/05/93	1.00	08:47	-0.25	0.75	1.08	0.2	1.7	1950	1.7				
MPB-9.5	05/06/93	2.00	14:00	-0.03	1.97	2.83	0.0	2.5	2000	1.5	HC with diluter.			
MPC-5	05/04/93	0.00	15:02	0.00	0.00	0.00	19.6	0.5	24	0.95		Trend of O2/	New	k
MPC-5	05/04/93	0.00	15:22	0.01	0.01	0.02	16.9	0.5	20	1.0		Time - MPC5	x-values	0.1231
MPC-5	05/04/93	0.00	15:33	0.02	0.02	0.03	13.2	0.5	41	1.2		17.5920649	0	
MPC-5	05/04/93	0.00	15:50	0.03	0.03	0.05	11.7	0.5	50	1.0		-0.87290502	0.15	
MPC-5	05/04/93	0.00	16:00	0.04	0.04	0.06	8.5	0.55	61	1.0				
MPC-5	05/04/93	0.00	16:10	0.05	0.05	0.07	6.9	0.5	68	1.0				
MPC-5	05/04/93	0.00	16:28	0.06	0.06	0.09	5.2	0.5	79	1.0				
MPC-5	05/04/93	0.00	16:57	0.08	0.08	0.12	4.1	0.6	140	0.79				
MPC-5	05/04/93	0.00	17:33	0.10	0.10	0.15	1.2	0.6	140	0.99				
MPC-5	05/04/93	0.00	18:12	0.13	0.13	0.19	0.4	0.6	210	1.0	HC with diluter.			
MPC-5	05/04/93	0.00	20:28	0.23	0.23	0.33	1.0	0.7	200	1.4	HC with diluter.			
MPC-5	05/05/93	1.00	08:54	-0.26	0.74	1.07	3.2	0.6	200	1.1	HC with diluter.			
MPC-5	05/06/93	2.00	14:05	-0.04	1.96	2.82	1.8	0.0	1080	1.3	HC with diluter.			

MPC-9.5	05/04/93	0.00	15:05	0.00	0.00	0.00	17.5	0.5	36	1.1		Trend of O2/	New	k
MPC-9.5	05/04/93	0.00	15:26	0.01	0.01	0.02	14.2	0.6	70	1.1		Time - MPC9.5	x-values	0.13976
MPC-9.5	05/04/93	0.00	15:41	0.03	0.03	0.04	11.0	0.7	105	1.2		16.066525	0	
MPC-9.5	05/04/93	0.00	15:54	0.03	0.03	0.05	8.8	0.6	120	0.99		-0.70479207	0.12	
MPC-9.5	05/04/93	0.00	16:01	0.04	0.04	0.06	5.5	0.8	190	1.1				
MPC-9.5	05/04/93	0.00	16:18	0.05	0.05	0.07	4.2	0.9	220	1.0				
MPC-9.5	05/04/93	0.00	16:41	0.07	0.07	0.10	3.0	0.95	240	1.2				
MPC-9.5	05/04/93	0.00	17:05	0.08	0.08	0.12	1.3	0.98	300	0.95				
MPC-9.5	05/04/93	0.00	17:37	0.11	0.11	0.15	1.0	1.0	340	0.98				
MPC-9.5	05/04/93	0.00	18:15	0.13	0.13	0.19	0.0	1.4	480	1.0	HC with diluter.			
MPC-9.5	05/04/93	0.00	20:33	0.23	0.23	0.33	0.6	1.8	620	1.4	HC with diluter.			
MPC-9.5	05/05/93	1.00	09:00	-0.25	0.75	1.08	0.5	2.1	67	1.2	HC reading in question.			
MPC-9.5	05/06/93	2.00	14:10	-0.04	1.96	2.83	0.0	4.1	1640	1.2	HC with diluter.			

Respiration Test
POL Area
Offutt AFB, NE

Monitoring Point	Date	Days Elapsed (frac. days)	Time	Hrs elapsed (fractional days)	Days Elapsed	Elapsed Time (min. x 1000)	O2%	CO2%	Total Hydro-carbon	Helium	Comments	Trend of O2/	New	k
OF3-VW	05/05/93	0.00	14:43	0.00	0.00	0.00	17.2	0.55	600	0.89		Time - VW	x-values	0.03314
OF3-VW	05/05/93	0.00	14:50	0.00	0.00	0.01	17.0	0.55	650	0.94		16.9512306	0	
OF3-VW	05/05/93	0.00	15:20	0.03	0.03	0.04	15.2	0.6	930	0.84		13.3057181	0.11	
OF3-VW	05/05/93	0.00	15:57	0.05	0.05	0.07	14.0	0.6	1250	0.85				
OF3-VW	05/05/93	0.00	16:33	0.08	0.08	0.11	13.8	0.65	1400	0.59				
OF3-VW	05/05/93	0.00	16:37	0.08	0.08	0.11	13.8	0.65	1400	0.57	Resample			
OF3-VW	05/05/93	0.00	20:30	0.24	0.24	0.35	10.0	0.8	1950	0.66				
OF3-VW	05/06/93	1.00	09:50	-0.20	0.80	1.15	9.0	0.97	2650	0.50				
MPC-4	05/05/93	0.00	14:12	0.00	0.00	0.00	20.8	0.5	15	0.53		Trend of O2/	New	k
MPC-4	05/05/93	0.00	14:30	0.01	0.01	0.02	20.8	0.5	17	0.33		Time - MPC4	x-values	0.00126
MPC-4	05/05/93	0.00	15:01	0.03	0.03	0.05	20.8	0.5	36	0.28		20.8025719	0	
MPC-4	05/05/93	0.00	15:30	0.05	0.05	0.08	20.7	0.5	57	0.33		19.3184462	1.18	
MPC-4	05/05/93	0.00	16:20	0.09	0.09	0.13	20.5	0.5	90	0.31				
MPC-4	05/05/93	0.00	20:39	0.27	0.27	0.39	20.4	0.5	140	0.29				
MPC-4	05/06/93	1.00	09:55	-0.18	0.82	1.18	19.3	0.55	250	0.19				

APPENDIX B

O&M INSTRUCTIONS

SYSTEM MAINTENANCE

This Appendix is a summary of the *Generic Bioventing Blower System Operations and Maintenance Manual for Extended Pilot Testing* (Engineering-Science, Inc., 1993) (O&M Manual). Copies of the O&M Manual have been supplied to Offutt AFB and should be referred to for additional details.

B.1 BLOWER/MOTOR MAINTENANCE

The blowers and motors are relatively maintenance free. There is no lubrication required because the blowers and motors have sealed bearings. If a blower system is in need of repair, please contact Jim Walters at (303) 831-8100.

B.2 FILTER MAINTENANCE

To avoid damage caused by passing solids through the blowers, an air filter has been installed inline before each blower. The inline air filter will prevent solids from entering the blower, and is rated at 99 percent efficiency to 10 microns.

The filter element is a polyester cloth and can be cleaned and reused, or replaced. The filters should be checked weekly for the first 2 months of operation. The air filters should be cleaned or replaced when the pressure difference across the filter reaches 15 to 20 inches of water. It is the responsibility of Offutt AFB to determine the best schedule for filter cleaning and/or replacement, depending on the results of the initial observations.

The filters can be checked after turning off the blower systems. To remove the filter, loosen the clamps, lift the metal top off the air filter, and lift the air filter from the metal housing. When replacing the filter, be careful that the rubber seals remain in place. The filter is manufactured by Solberg Manufacturing, Inc. in Itasca, Illinois. Their phone number is (708) 773-1363. The filters can also be obtained through Fluid Technology, Inc. in Denver, Colorado. The contacts there are Mr. Bob Cook and Mr. Greg Sparks; they can be reached at (303) 233-7400. It is recommended that AFP 4 keep a spare air filter at the site.

B.3 BLOWER PERFORMANCE MONITORING

To monitor the blower performance, vacuum, pressure, and temperature will be measured. These data will be recorded on the data collection sheets provided. All measurements will be taken at the same time while the system is running.

B.3.1 Pressure/Vacuum

Open the shed roof and record the pressure and vacuum readings directly from the gages in inches of water. Record the measurements on the data collection sheet provided.

B.3.2 Temperature

Open the shed roof and record the temperature readings directly from the gages in degrees Fahrenheit. Record the measurements on the data collection sheet provided.

B.4 MONITORING SCHEDULE

The following monitoring schedule is recommended for this system. During the initial months of operation, more frequent monitoring is recommended to ensure that any start up problems are quickly corrected. Data collection sheets have been provided to record the system data.

Monitoring Item	Monitoring Frequency
Blower vacuum and temperature	Weekly for the first 2 months of operation. AFP 4 personnel then may optimize the schedule depending on the results of initial observations.